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BLS-3 Balloon Locating System

HANS LAPING
ALAN R. GRIFFIN

12 April 1977

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FOR THE COMMANDER

John Howard

Chief Scientist

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A small light-weight balloon tracking system using the VHF Omnidirectional Range (VOR) network has been designed, developed, and flight tested by AFGL's Aerospace Instrumentation Division. This report includes VOR theory, a description of the BLS-3 tracking instrument, and instructions for its use on balloon flights.

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Preface

The authors wish to thank TSgt Coriaty and SSgt Blanchard for their assistance in the development and flight testing of the BLS-3 balloon tracking system and Robert Vesprini for his development of a computer program which calculates balloon positions from VOR station data.

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Contents

Illustrations

BLS-3 Balloon Locating System

1. INTRODUCTION

This report serves a dual function; it describes the BLS-3 VOR balloon locating system (see Figure 1) and it also serves as a user's manual.

1.1 VHF Omnirange Concepts and Theory

The VHF Omnidirectional Range (VOR) system is a network of ground transmitters operated and maintained by the FAA for aircraft navigation across the United States. It is widely used by all types of commercial and military aircraft.

At present there are approximately 1200 VOR stations across the United States operating on 100 channels (soon to be expanded to 200 channels) in the 108- to 118-MHz frequency band. Each station is assigned a carrier frequency within this band. Several stations transmit on the same frequency at different geographical locations. These co-channel stations are separated by a distance sufficient to prevent RF interference with each other. The radiation pattern of each station is an omnidirectional, horizontally polarized, vertical cone which can be received within line-of-sight. Our experience has shown that on high altitude balloon flights good VOR signals (10 μV or greater) can be received at distances of 250 miles or more from a VOR station.

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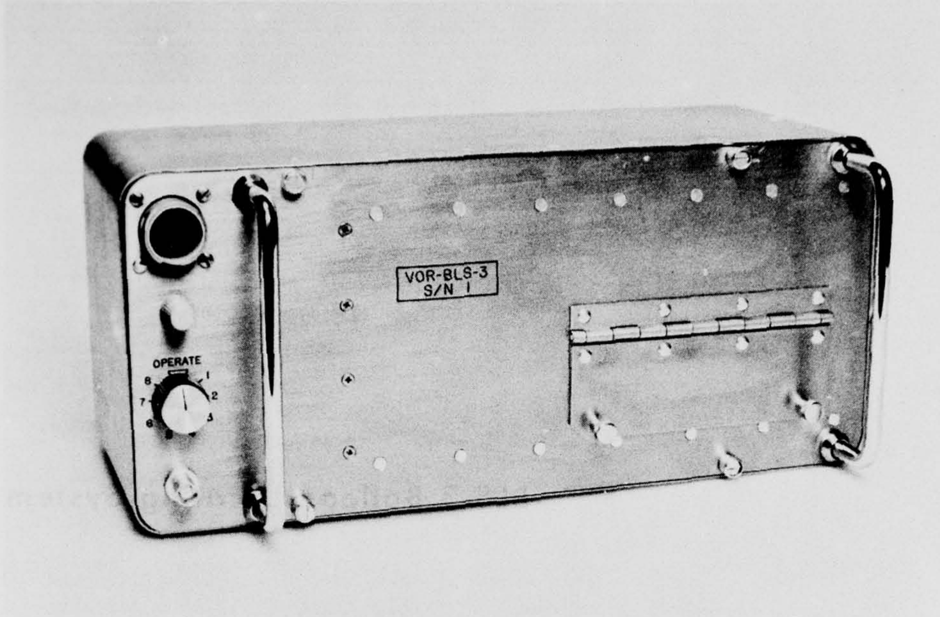

Figure 1. BLS-3 Instrument

The VOR stations provide navigational signals for VOR aircraft receivers that allow a navigator to determine the bearing angle of his position relative to the VOR station being monitored. This bearing angle is created by the phase difference between two 30-Hz signals modulated on a VHF carrier. One of these signals is called the 30-Hz reference signal. This constant-phase reference signal frequency-modulates a 9960-Hz subcarrier with a deviation of ±480 Hz which, in turn, amplitude-modulates the VOR carrier. The phase of the 30-Hz reference signal is constant at all azimuths about the VOR station. The other signal is called the 30-Hz variable signal. The phase of this 30-Hz variable signal changes one electrical degree with each azimuth degree around the VOR station. This variable phase signal is produced by space-modulation of the radiated RF carrier. Space modulation is usually accomplished by phasing antenna patterns.

The VOR receiver detects the variable signal as an amplitude-modulated 30-Hz signal. At magnetic North from a VOR station the 30-Hz reference and variable signals are in phase. As one follows the radiation pattern clockwise around the VOR station the 30-Hz variable signal lags the 30-Hz reference signal. This phase difference is measured by the VOR receiver and is used to determine the bearing angle from the aircraft to the VOR station or, in our case, the balloon to the VOR station.

In addition to the navigation signals, VOR stations also broadcast voice and Morse code. These signals, like the 30-Hz variable signal, amplitude-modulate the carrier and are used for station identifiers, weather broadcasts, and communication with aircraft. If the reader desires more detailed information, many FAA publications can be consulted.

2. BALLOON-BORNE VOR PROCESSOR CONCEPT

AFGL's balloon tracking system, BLS-3, utilizes VOR navigation signals from two or more stations to establish the geographical position of its free floating balloons.

A simplified block diagram of a balloon-borne VOR navigation instrument is shown in Figure 2. Before a balloon flight, the instrument is programmed for eight different VOR frequencies corresponding to eight or more stations located in the general vicinity of the projected flight path of the balloon. Upon command from the ground control station or by its own internal timer, the balloon-borne instrument receives the VOR signals, measures the bearing angles from the balloon to the VOR stations, digitizes these angles, and transmits the digitized data back to the ground monitor station. On the ground the data is decoded and used to plot or calculate the balloon position.

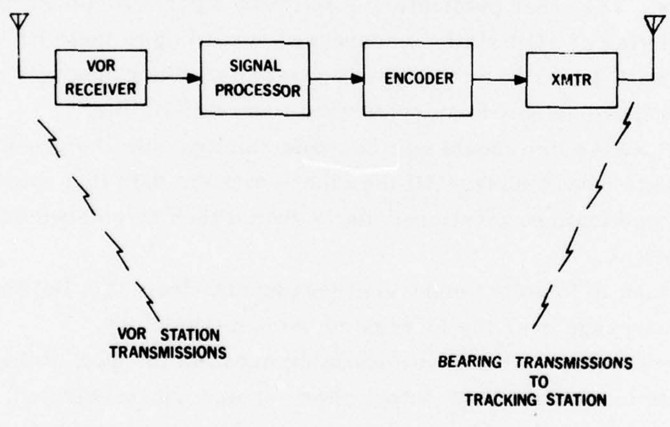

Figure 2. Simplified Block Diagram of a Balloon-Borne VOR Instrument

2.1 Pre-Flight Station Selection

Selecting VOR stations for tracking a free balloon is an important consideration. This selection should be based on the trajectory forecast just prior to flight. The key to selecting the best stations is always to keep this trajectory in mind as an overall picture. VOR stations must be selected along this trajectory to provide adequate tracking coverage throughout the entire flight.

The first step in the selection process is to plot the forecast trajectory on a map. Aeronautical charts are the best maps to use because they show the locations of VOR stations. Stations located both along this trajectory and within 150 miles to either side of it should then be noted as possible selections for use in flight. The number of selections need not be limited to eight. In fact, all stations on the map that appear usable along the trajectory should be noted. Some of these stations will be eliminated upon examining pertinent VOR station data such as limited RF power output, any areas around a station where the VOR signal is unusable, and the presence of other stations along the trajectory that radiate on the same frequencies.

There are two good publications that contain pertinent data on VOR stations. One of these is the IFR Supplement, which is a flight information book published by the Defense Mapping Agency. It contains an alphabetical listing of all United States Aerodromes. Under each Aerodrome is a section called Radio Aids to Navigation where VOR station data is listed. This list includes the station's RF carrier frequency and those areas around the station, if any, where the VOR signal is unusable. The other publication is the FAA Master Radio Frequency List. It contains a listing of VOR stations sequenced according to their RF carrier frequencies. The RF power of a station and a list of all other channels on the same frequencies as those selected can be derived from this listing.

A comprehensive list should now be made starting with the preselected VOR stations and their co-channels. All the other pertinent data that was extracted from the VOR publications mentioned above should then be entered next to all of these VOR stations.

The next task is to select eight VOR frequencies from this list that will provide the best coverage over the forecasted balloon trajectory.

As a general rule, stations with unusable areas in the path of the trajectory or stations with less than 200-W output power should not be selected. However, data from the co-channels of these stations must be considered before eliminating them. If there are a number of co-channels of a particular station that do not have any of the same marginal characteristics, they may be useful at points farther along the trajectory where more tracking coverage is needed. Therefore, the decision to select a frequency for flight must be a judgment based on how all

the pertinent VOR station data interacts. This judgment is the most critical on long trajectory flights.

The eight frequencies that result from this selection process can now be programmed into the BLS-3 instrument.

2.2 Programming the BLS-3

Frequencies are programmed into the BLS-3 with eight miniature dual-in-line switch packages, one for each channel. Each switch package contains 10 miniature switches. These switches are located beneath the hinged door on the front panel of the instrument (see Figure 3). To program a frequency, a total of four switches must be activated, two for the tenths MHz value and two for the units MHz value. Table 1 is a coding of the switches that must be activated to program a desired frequency into one channel of the BLS-3 instrument. To program 109.6 MHz, for example, requires the activation of switches 6 and 10 and 1 and 3.

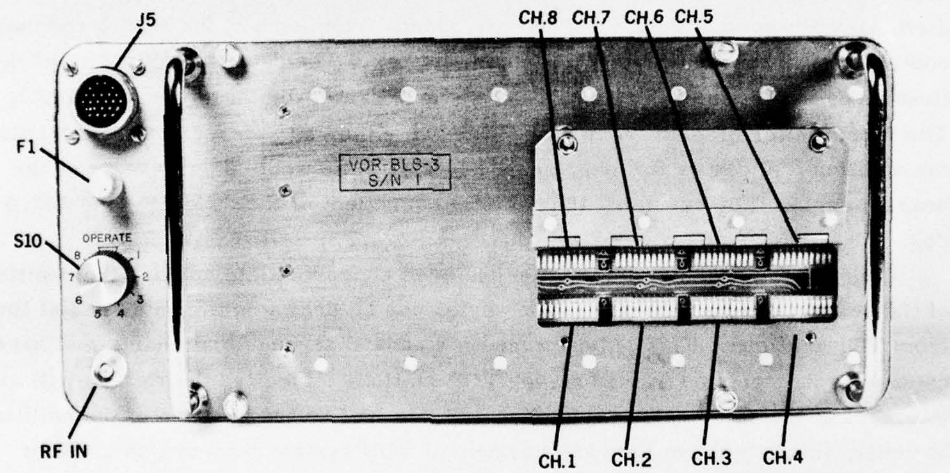

Figure 3. BLS-3 Front Panel Controls

Table 1. BLS-3 Programming Table

Freq (MHz)	Switches Activated	Freq (MHz)	Switches Activated
108	7 + 10	.0	1 + 4
109	6 + 10	.1	4 + 5
110	6 + 9	.2	3 + 5
111	9 + 10	.3	3 + 4
112	8 + 10	.4	2 + 4
113	8 + 9	.5	2 + 3
114	7 + 9	.6	1 + 3
115	7 + 8	.7	1 + 2
116	6 + 8	.8	2 + 5
117	6 + 7	.9	1 + 5

2.3 Balloon Position Plotting

Bearing information received from the BLS-3 at the ground tracking station is copied as Morse code letters and translated into decimal angles using the code dictionary shown in Figure 4. The code groups from each of the BLS-3 channels contain a combination of four Morse code letters. The decimal equivalent of the first three letters in each group is the whole degree value of the bearing angle. The fourth letter of each group will always be either an S or a D and represents the addition of 0 deg or 0.5 deg, respectively, to the whole degree value of the bearing angle. For example, the decimal equivalent of the code RSKD is 133.5 deg.

Once all the bearing information has been converted into angles, the position of the balloon can be plotted. These angles can be drawn on a map as radial lines from VOR stations. This is best done on standard aeronautical charts that have compass roses printed around all the VOR stations. Ideally, the radials will all intersect at the same point on the map and this will be the position of the balloon; however, this is seldom the case because of VOR system inaccuracies. What normally results is a small triangle formed by the intersections of three radial lines. The balloon position must then be fixed within this triangle. This fix should be biased within the triangle towards the station(s) with the least probability of error relative to the present balloon position. VOR station errors increase the farther they are from the balloon. They also increase if mountains between the station and the balloon even partially block line-of-sight. Also, errors will increase as the angle formed by two intersecting radials approaches 180°, even though the bearing from each of the two stations involved is accurate.

Morse Code	S	U	R	W	D	K	G	O
SS	0	1	2	3	4	5	6	7
SU	8	9	10	11	12	13	14	15
SR	16	17	18	19	20	21	22	23
SW	24	25	26	27	28	29	30	31
SD	32	33	34	35	36	37	38	39
SK	40	41	42	43	44	45	46	47
SG	48	49	50	51	52	53	54	55
SO	56	57	58	59	60	61	62	63
US	64	65	66	67	68	69	70	71
UU	72	73	74	75	76	77	78	79
UR	80	81	82	83	84	85	86	87
UW	88	89	90	91	92	93	94	95
UD	96	97	98	99	100	101	102	103
UK	104	105	106	107	108	109	110	111
UG	112	113	114	115	116	117	118	119
UO	120	121	122	123	124	125	126	127
RS	128	129	130	131	132	133	134	135
RU	136	137	138	139	140	141	142	143
RR	144	145	146	147	148	149	150	151
RW	152	153	154	155	156	157	158	159
RD	160	161	162	163	164	165	166	167
RK	168	169	170	171	172	173	174	175
RG	176	177	178	179	180	181	182	183
RO	184	185	186	187	188	189	190	191
WS	192	193	194	195	196	197	198	199
WU	200	201	202	203	204	205	206	207
WR	208	209	210	211	212	213	214	215
WW	216	217	218	219	220	221	222	223
WD	224	225	226	227	228	229	230	231
WK	232	233	234	235	236	237	238	239
WG	240	241	242	243	244	245	246	247
WO	248	249	250	251	252	253	254	255
DS	256	257	258	259	260	261	262	263
DU	264	265	266	267	268	269	270	271
DR	272	273	274	275	276	277	278	279
DW	280	281	282	283	284	285	286	287
DD	288	289	290	291	292	293	294	295
DK	296	297	298	299	300	301	302	303
DG	304	305	306	307	308	309	310	311
DO	312	313	314	315	316	317	318	319
KS	320	321	322	323	324	325	326	327
KU	328	329	330	331	332	333	334	335
KR	336	337	338	339	340	341	342	343
KW	344	345	346	347	348	349	350	351
KD	352	353	354	355	356	357	358	359
KK	360							

Figure 4. Code Dictionary (Morse Code)

A simpler and more accurate method of plotting balloon positions from VOR bearing angles has recently been developed. A computer program has been written for the HP-9810A programmable calculator which calculates the balloon position from the VOR station coordinates and their bearing angles to the balloon. These calculations are based on spherical geometry. Therefore, errors due to the plotting of radials on a map and distortions in the projection of the map are eliminated.

The program stores the coordinates of eight VOR stations. The coordinates of every programmed station are corrected for the local magnetic variation because all bearing angles are with respect to magnetic North. Any three of the eight station bearings are used to calculate the balloon position. In this manner, the path of the balloon can be tracked over a long distance without changing the program. The user can choose the station combinations which will generate the optimum fix (90° crossings). The calculator generates and prints the coordinates of the combinations of three VOR stations. These fixes can be plotted on any map.

3. TEST RESULTS

One of the reasons behind the design of the BLS-3 instrument was to eliminate dependence on other agencies for tracking support. Therefore, test flights were conducted to compare the BLS-3 with other proven tracking devices.

On a 48-hr flight conducted from Chico, California, 130 fixes from the BLS-3 were compared with those from an FAA transponder and a Radiosonde. Other than two questionable fixes from the FAA transponder, the fixes from all three tracking devices never differed by more than 3 miles. On two occasions, the FAA transponder fix differed from the BLS-3 by about 25 miles; however, on each occasion, a fix from the tracking aircraft confirmed the BLS-3.

It should be noted that Radiosonde fixes ended after about 6 hours because line-of-sight to the balloon was lost. The BLS-3 is used in combination with an HF transmitter so it does not depend on line-of-sight. In addition, the accuracy of Radiosonde fixes decreases as the distance from the tracking station to the balloon increases. Since the BLS-3 monitors VOR stations along the balloon trajectory, the distance from the tracking station to the balloon has no effect on the accuracy of fixes. This gives the BLS-3 a unique advantage over the Radiosonde on long distance balloon flights.

The BLS-3 also demonstrated an advantage over the FAA transponder on this flight. Transponder fixes are not always available on a regular basis because FAA flight centers are often busy with normal air traffic control duties. The BLS-3 fixes are received directly at the balloon tracking station on a regular schedule.

Three flights were conducted from Holloman AFB, N. M., to compare BLS-3 fixes with radar fixes. On two of these flights the balloon was skin tracked by White Sands Missile Range radar. One of these flights was flown for 23 hours, the other for 72 hours. During the 23-hr flight, over 100 BLS-3 fixes were taken. Over 600 fixes were taken during the 72-hr flight. BLS-3 and radar fixes rarely disagreed by more than 3 miles on both of these flights. Again, the BLS-3 demonstrated its unique advantage when line-of-sight to the balloon was lost. Like the Radiosonde, radar depends on line-of-sight.

On the third comparison flight, White Sands Missile Range provided a C-band transponder and digital radar. Approximately 50 BLS-3 fixes were received and compared with the radar fixes, resulting in differences of only 1 mile or less. It should be noted that the balloon was always within line-of-sight on this flight. Since there are many flights of this nature, radar coverage alone would be more than adequate for tracking. The objective of this test flight was to demonstrate the accuracy of the BLS-3 instrument. This objective was met.

As a result of these tests, the BLS-3 is now considered an operational unit and production models are presently under fabrication.

4. TECHNICAL DESCRIPTION OF THE BLS-3

4.1 General

The BLS-3 instrument takes advantage of the latest technological advances, expecially in the integrated circuits field. Wherever possible low power, high noise immunity, complementary symmetry metal oxide semiconductor integrated circuits (C-MOS) are utilized. The unit consists of three circuit boards and a VOR receiver housed in a protective, shielded enclosure (see Figure 1). The technical characteristics are given in Table 2 and the internal wiring diagram is shown in Appendix A. The operating principles of the BLS-3 are described with the aid of the block diagram of Figure 5. Before flight the unit is programmed for eight different VOR frequencies corresponding to eight or more VOR stations located in the projected flight path of the balloon. The system is activated by command or by its own timer (selectable for 7.5-, 15-, or 30-min intervals). Upon system activation the receiver detects the bearing signal from the VOR ground station. The output of the receiver feeds the signal processing circuits where the 30-Hz reference signal is detected by the 9960-Hz PLL (phase-locked loop), filtered and phase locked to a 30-Hz PLL. The 30-Hz variable signal, which amplitude-modulates the carrier, is also filtered and phase locked to another 30-Hz PLL.

Table 2. Technical Characteristics of BLS-3

Frequency range	108 to 118 MHz (100 kHz increments)
Number of programmable frequencies	8
Threshold sensitivity	5 μV to 1000 μV adjustable
RF input impedance	50 ohms
Bearing accuracy	$\pm 0.25^{\circ}$
Bearing resolution	0.5°
Power requirements	+12 V at 350 mA average
Operating temperature range	-40°C to $+55^{\circ}$C
Size	13 x 6 x 5.5 in.
Weight	8.5 lb

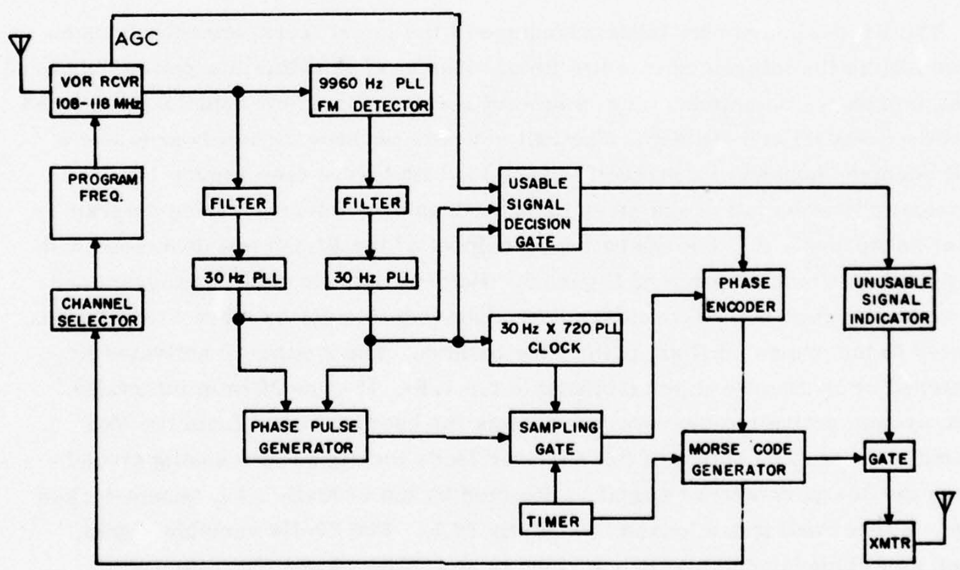

Figure 5. Block Diagram of the BLS-3 Instrument

It should be noted here that both 30-Hz signals are derived from the 60-Hz power-line frequency at the VOR ground station; therefore, phase jitter and small variations of frequency can exist. The problem of phase jitter on the 30-Hz variable is even more pronounced because the signal is amplitude modulated with other signals such as voice and the station's identifier code, which creates a number of intermodulation products and distortion. By using phase-locked loops and filters these problems are almost eliminated. In fact, laboratory bench tests indicate a 5 to 1 accuracy improvement when phase-locked loops are used as signal conditioners instead of conventional filtering.

The outputs of each 30-Hz PLL are used to set and reset a flip-flop which, in turn, creates the phase difference between the two 30-Hz navigation signals. The output of the 30-Hz reference PLL is also used to synthesize the 21, 600-Hz (720×30 Hz) phase measurement clock. This clock is in phase with the 30-Hz reference signal which is synchronized to the local power frequency at the VOR station. Therefore, small variations of the power-line frequency will not introduce any errors in the phase measurements. Because of this synchronization the usual ± 1-bit ambiguity is also eliminated. The width of one phase pulse determines how many clock pulses the phase encoder counts. Since the clock frequency is 30×720 Hz, the bearing resolution is 0. 5 deg.

The phase encoder feeds the code generator, which serializes the bit count into an octal or Morse code, where dots correspond to binary 0's and dashes to binary 1's. The code is grouped into 3 bits per character and 4 characters per word. One word represents the bearing angle from the VOR station to the balloon. The decimal equivalent of the first 3 letters represents whole degrees, while the last letter indicates the addition of either 0 deg or 0. 5 deg to the bearing angle. The serialized output of the code generator modulates the on-board transmitter which radiates the information to the ground station.

After the first channel readout, the instrument automatically sequences through the remaining channels, measuring bearing angles and transmitting the data to the ground station.

When eight VOR frequencies are programmed for a projected trajectory it often occurs that some of the VOR station signals are not received throughout the whole flight because of long distances from the balloon to the station. Only line-of-sight signals can be received. Previously we assumed that good signals existed for all programmed VOR stations; however, this condition will only exist if the instrument receives a usable signal on all eight frequencies. A signal is usable if the magnitude of the RF carrier is above a preset threshold and if both 30-Hz navigation signals are present. This is an important criterion because this frequency band, 108 MHz to 118 MHz, is also used to transmit landing-aid signals for aircraft. The RF threshold level is usually set to 10 μV to establish a good

signal-to-noise ratio. From a typical VOR station with 200 W of output power, the signal strength is better than 10 μV at distances of 250 miles or more as long as the balloon is within line-of-sight with the VOR station. If the received signal fails to meet one or more of the above criteria, a decision gate overrides the code generator and a 2-sec dash is transmitted to the ground station indicating that a non-usable signal exists.

In order to compute or plot a balloon position, at least two of the eight programmed channels must have a usable signal. With eight VOR frequencies, provided they are carefully chosen, it is possible to track a free floating balloon anywhere in the continental United States.

4.2 VOR Receiver

The VOR navigation receiver is model RNA-26C manufactured by Bendix Corporation. (See Figures 6, 7, 8.) It is powered by a 12- to 16-V dc/dc converter located on the main chassis. (See Figure 9.) Only the RF and IF sections are used in the BLS-3. The receiver was slightly modified to eliminate phase shift in the 30-Hz variable signal with increasing RF input signal. Two 100 μf capacitors were added to the AGC circuit. (See Figure 7.) The receiver employs double conversion for good selectivity. Frequency selection is accomplished by digital tuning of the varactors in the front end and simultaneously selecting two crystal oscillators. There are 20 fixed frequency crystals in the unit. A 2 out of 5 code is used to select a particular crystal. In this manner the 1-MHz and the 100-kHz increment oscillators are selected. The frequency selection process is controlled by the programmable channel selector circuit board. If more information about the VOR receiver is required, the RNA-26C manual should be consulted.

4.3 Programmable Channel Selector Circuit Board

The BLS-3 programmable channel selector sequentially tunes the VOR receiver to the frequencies programmed by the eight miniature DIP switch packages on the circuit board. Each switch package contains 10 SPST switches. Programming of these switches is described in Section 2.2.

The circuit can operate in an automatic or manual mode. These two modes are selected by a 10-position rotary switch (S10) located on the front panel of the instrument (see Figure 3). The two positions labeled OPERATE place the BLS-3 into the automatic mode. In this mode the unit sequentially steps through all eight channels. The remaining eight positions place the unit into the manual mode and select the channel indicated.

The manual and automatic modes of operation are controlled by IC12 and IC14. These two IC's contain eight, dual-input, AND/OR select gates. One input of each

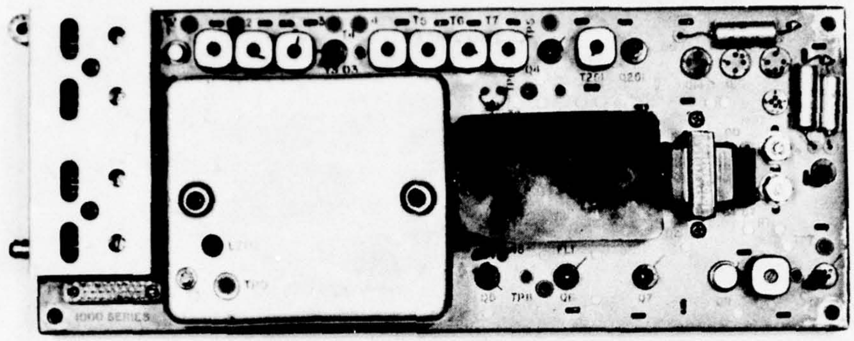

Figure 6. VOR Receiver (Top View)

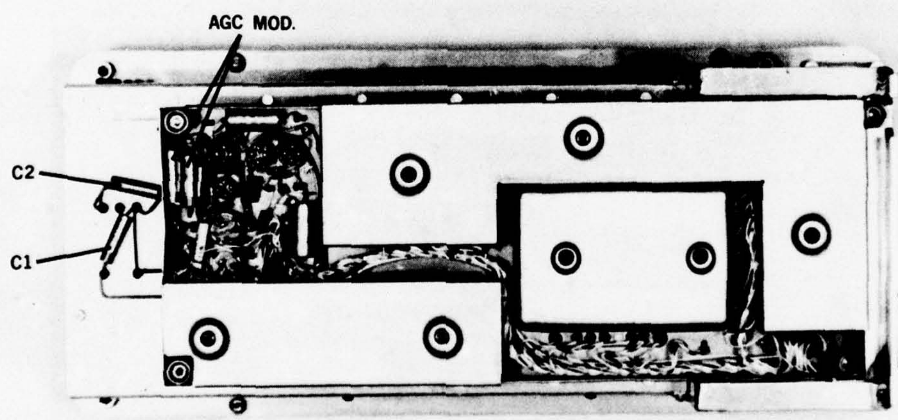

Figure 7. VOR Receiver (Bottom View)

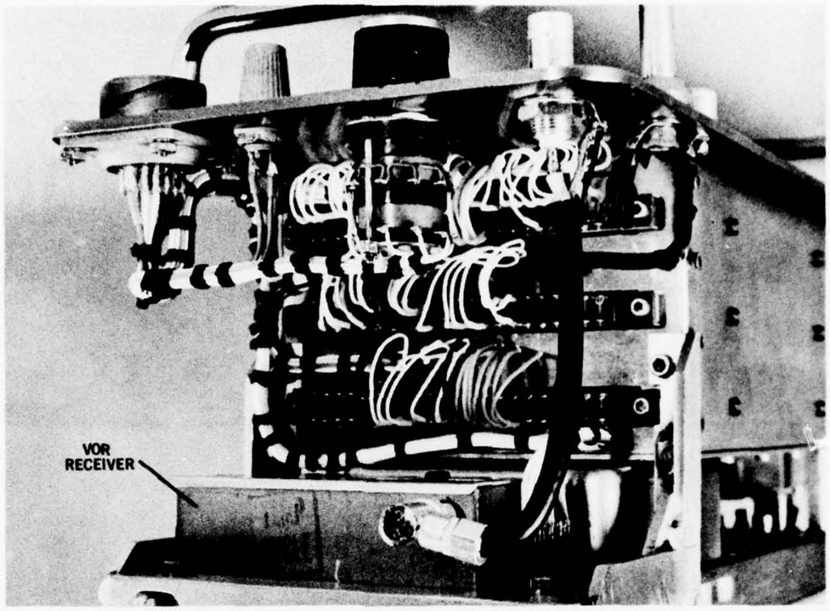

Figure 8. BLS-3 Internal Wiring

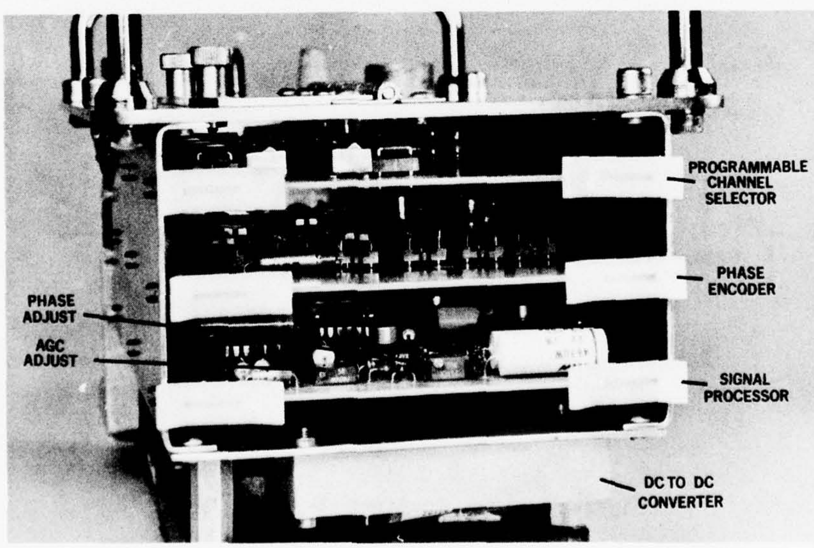

Figure 9. BLS-3 Main Chassis

gate is connected to the MANUAL/OPERATE switch (S10). These are the eight manual channel select lines. The other input of each gate is connected to the automatic channel selector, IC13, which sequentially selects the eight channels in the BLS-3. Each output of IC12 and IC14 drives one of the diode matrices, IC1 through IC8. The matrix pattern in each of these IC's is formed by burning out the fusible links to any unused diodes. Figure 10 shows the diode matrix program and Figure 11 is a schematic of the programmable channel selector. The diodes in these matrices that are used provide isolation for each of the programming switches. Each actuated switch drives the corresponding output transistor into saturation, which grounds its frequency-select line. A frequency is selected when two of the 1.0-MHz select lines and two of the 0.1-MHz select lines are grounded.

In the automatic mode a logical "1" is placed on pin V of the circuit board. This enables the automatic channel select lines of IC13. At the start of the BLS-3 readout cycle, the phase encoder feeds a reset pulse to pin 10 which sets the automatic channel selector, IC13, to channel 1. The VOR receiver then tunes to the frequency programmed on channel 1 and stays tuned until a phase measurement has been made. After the phase measurement, the phase encoder feeds a clock pulse (channel shift) to pin 9 which causes the channel selector, IC13, to advance to the next channel. This sequence continues until all eight phase measurements have been made. The programmable channel selector then waits for a new readout cycle and the same sequence is repeated.

In the manual mode a logical "1" is placed on pin 11 of the circuit board. This enables all manual channel select lines and also prevents channel switching by inhibiting the clock to the channel selector, IC13. Each channel can be manually selected with switch S10. This feature simplifies pre-flight testing.

4.4 Signal Processor Circuit Board

The signal processor contains the 8-V regulator, IC63, which supplies power to all integrated circuits in the BLS-3. The 30-Hz reference signal detector, active filters and PLL signal conditioners for both 30-Hz signals, the phase pulse generator, and the usable-unusable signal detector are also located on this circuit board. Refer to the schematic diagram in Figure 12 for the following description of the processor circuit board.

The composite navigation signal from the receiver feeds pin H of the signal processing board. At this point the composite signal is split into two separate paths. The 9960-Hz signal is high passed by C56 and fed into the PLL FM detector, IC52, where the 30-Hz reference signal is extracted. The output of IC52 is band passed by active filter, IC59, and squared by IC58. IC58 feeds the PLL signal conditioner, IC62, where more filtering and phase jitter elimination occurs.

The positive transition of the output of IC62 sets the phase pulse generator flip-flop, IC60, and also feeds the 21.600-kHz PLL clock generator on the phase encoder board.

The 30-Hz variable signal from the receiver follows a similar path. It feeds two active filters IC53 and IC56. Two filters are used because there is more distortion on this signal. The output of IC56 is squared by IC55 which feeds the PLL signal conditioner, IC61, where further filtering and phase jitter elimination takes place. The positive transition of the output of IC61 resets the phase pulse generator flip-flop, IC60. The output of IC60 is a pulse train generated by the set and reset action of the reference and variable signals. The width of each output pulse is the phase difference between the two 30-Hz signals. The phase pulses (pin L) feed the phase encoder board (pin 6) where the phase measurements are made.

The inputs (pins 3, 4, 5) to the decision gate, IC57, determine whether a VOR signal is usable or unusable. A VOR signal is usable when all three inputs of IC57 are low. This causes pin K of the circuit board to switch to a logical "0" indicating a usable signal to the phase encoder. If any input of IC57 is high, an unusable signal indication is fed to the phase encoder. Input pins 3 and 4 of IC57 are controlled by the dual 30-Hz PLL detector, IC54. The pin 5 input of IC57 is controlled by the AGC voltage comparator, IC51. The output pins 3 and 6 of IC54 are only low when both the reference and variable 30-Hz navigation signals are present.

The voltage comparator IC51 compares the receiver AGC voltage against a threshold voltage preset with potentiometer, R87. This potentiometer is usually adjusted for a receiver threshold sensitivity of 10-μV RF input. As long as the RF input to the receiver is above 10 μV the output of the voltage comparator stays low.

4.5 Phase Encoder Circuit Board

The phase encoder is the heart of the BLS-3 instrument. It generates the read-out cycle intervals (selectable for 7.5, 15, or 30 min), measures the phase difference between the two 30-Hz navigation signals, and converts the result of each phase measurement into four 3-bit Morse code letters. Binary 1's are represented by dashes and binary 0's by dots. The decimal equivalent of the first three letters represents whole degrees and the last letter indicates the addition of either 0 or 0.5 deg to the angle.

Refer to the phase encoder schematic diagram (Figure 13). Two separate voltages are used to power this circuit board. A 12-V supply with reverse polarity protection powers the relay circuits, K1, K2, and K3. A regulated 8-V supply feeds all integrated C-MOS circuits. The crystal oscillator, Y1, generates a frequency of 74.565 kHz. This frequency is divided by two 14-stage binary counters, IC37 and IC38. The Q11, Q12, and Q13 outputs of IC38 generate the

7.5-, 15-, and 30-min timing intervals. One of these timing pulses is selected by S9 and fed to the clock input of flip-flop IC36. This flip-flop is reset by Q1 of IC38, 0.44 sec after every timing input from S9. The output of pin 6 of IC32 stays high for approximately 1 sec after every timing interval pulse. This creates a 1-sec alert dash via pin 5 of IC24 and the relay closure of K3. At the same time, the logical "1" on pin 6 of IC32 sets the channel counter on the programming board to channel 1 via pin R. It also resets IC25 and IC29 which, in turn, resets IC27 and IC30. After one second the output on pin 6 of IC32 switches to a logical "0," which allows IC25 to count the main clock pulses. Q5 of IC25 switches to a logical "1" after a 1.75-sec (16×109.8 msec) pause. This disables pin 10 of IC25 inhibiting the main clock pulses to IC25. It also enables pin 3 of IC31 which starts the phase measurement cycle.

The following is a description of a 180-deg phase measurement and its read-out cycle. Refer to the waveform diagram of Figure 14. After pin 3 of IC31 is enabled, the next negative transition of the main clock switches $\overline{Q1}$ and $\overline{Q2}$ of IC35 to zero. This enables the reset lines of IC22 and IC34. Then the next positive transition of the phase pulse enables pin 10 of the NAND gate, IC32, because the phase pulse and Q1 of IC34 are simultaneously high (for one phase pulse duration). Therefore, the NAND gate (IC32-10) is enabled until 360 clock pulses from the synthesized 21.600-kHz clock are passed through the gate and counted by the phase counter, IC22. The 21.600-kHz clock is synthesized from the 30-Hz reference signal and multiplied by 720 in the PLL, IC39, which creates a resolution of 0.5 deg. The output waveform of IC39 is shaped by IC36, resulting in a 5 percent duty cycle of the clock pulses. By shaping the clock pulses in this manner, the phase measurement quantization error is minimized, because the gate (IC32-10) is only enabled for the duration of the positive output of the clock pulses.

The phase counter, IC22, stores a count of 360 ($360 \times 0.5^{\circ} = 180^{\circ}$), which sets outputs Q9, Q7, Q6, and Q4. (The reset and the clock of IC22 also feed the BLS-3 test box counters via pins 7 and N. Therefore, the test box counters store and display the same angle.)

The negative transition of the 17th main clock pulse starts the read-out cycle. Reference should be made to the read-out cycle waveform diagram (Figure 15). After the phase measurement cycle has been completed, $\overline{Q1}$ of IC35 switches the channel counter, IC13, on the programming board to channel 2. At the same time the $\overline{Q2}$ output of IC26 is inverted by IC31-10 and triggers the flip-flop, IC29.

The output, $\overline{Q2}$ of IC29, enables the resets R of IC30, R1 of IC29, and R1 and R2 of IC27. The content of the phase counter, IC22 (which contains the number 360) and all other preset inputs are jammed into the shift-registers, IC21 and IC23, along with all other preset inputs. All 10 bits of IC22 are used to represent the phase measurement value. The binary equivalent of 360 is 010, 110, 100, 000, or

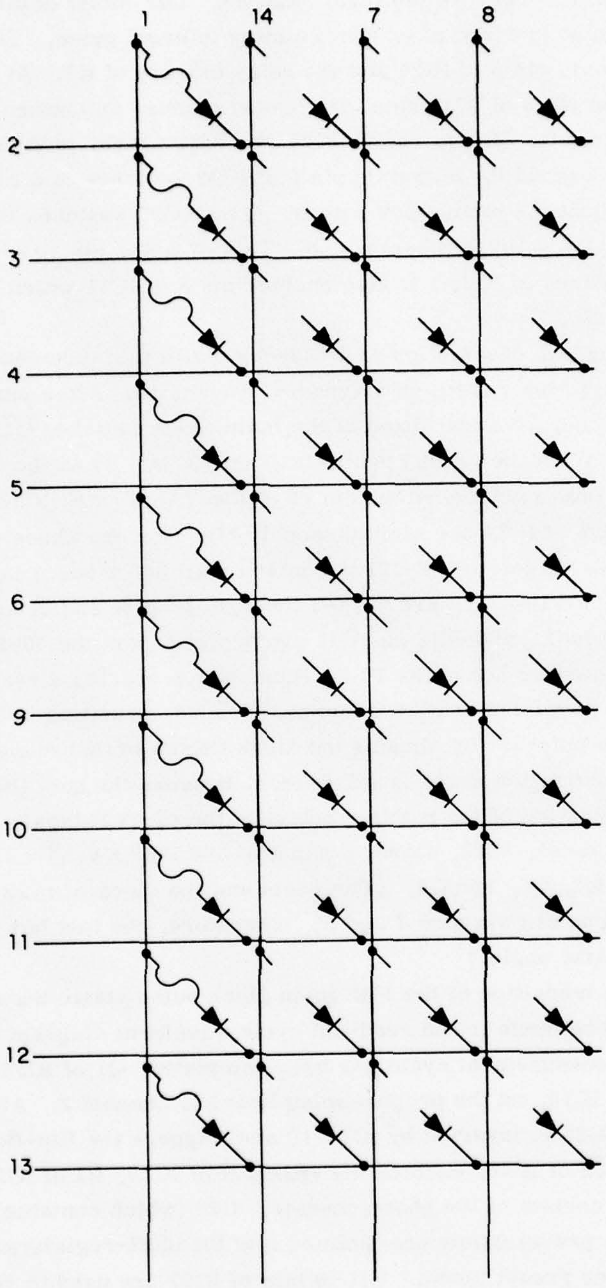

Figure 10. Diode Matrix Program

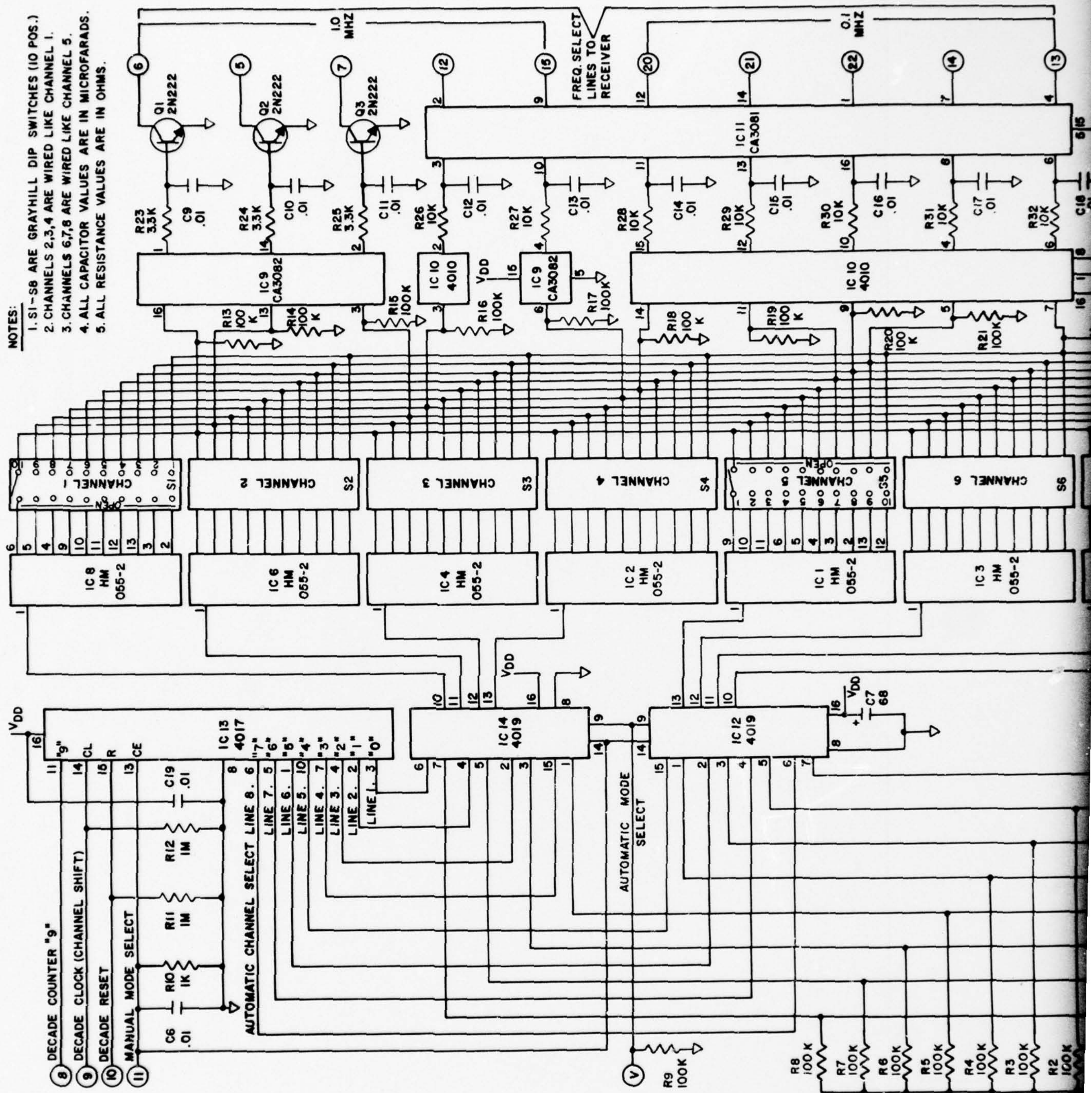

Figure 11. Programmable Channel S

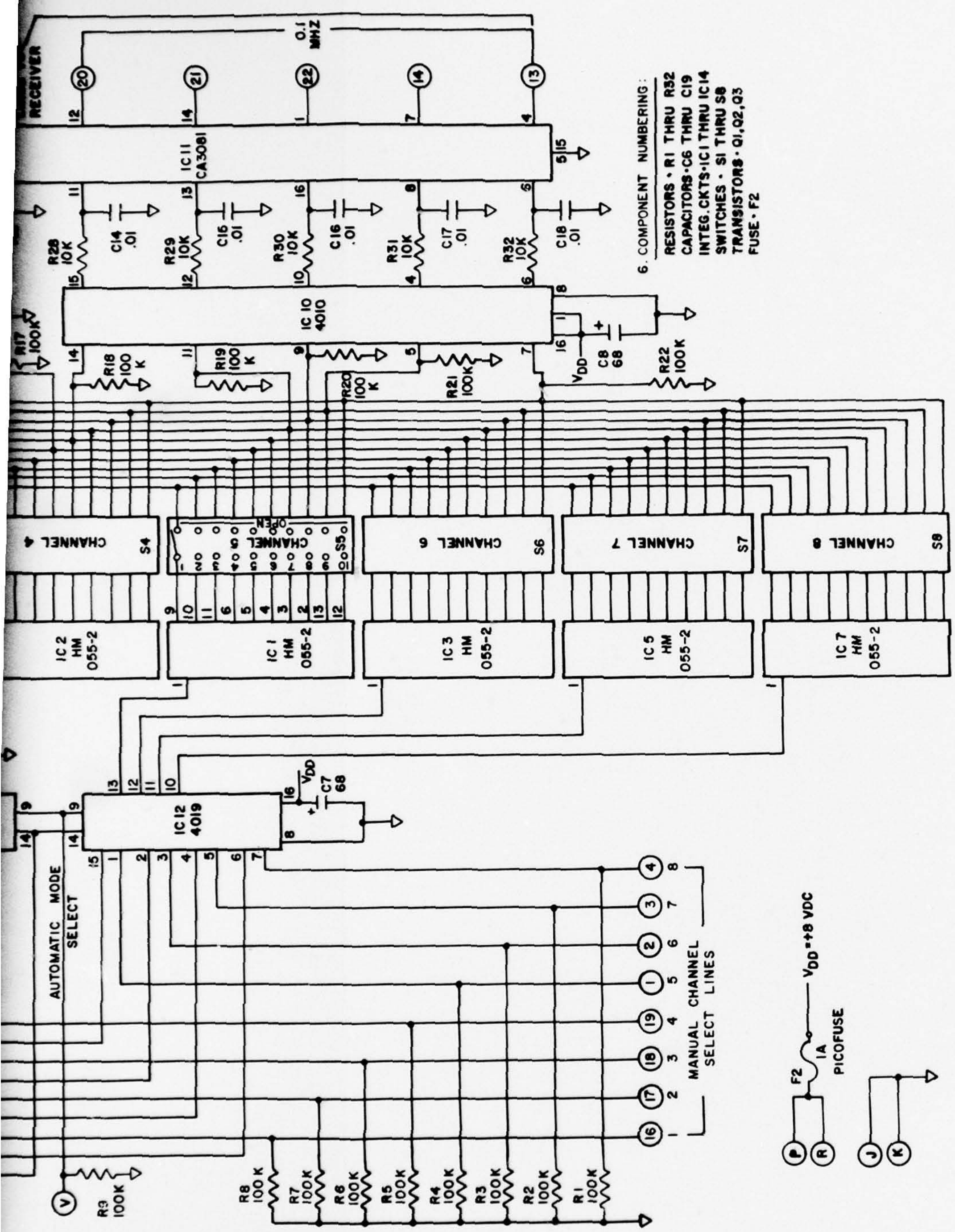

Figure 11. Programmable Channel Selector Schematic Diagram

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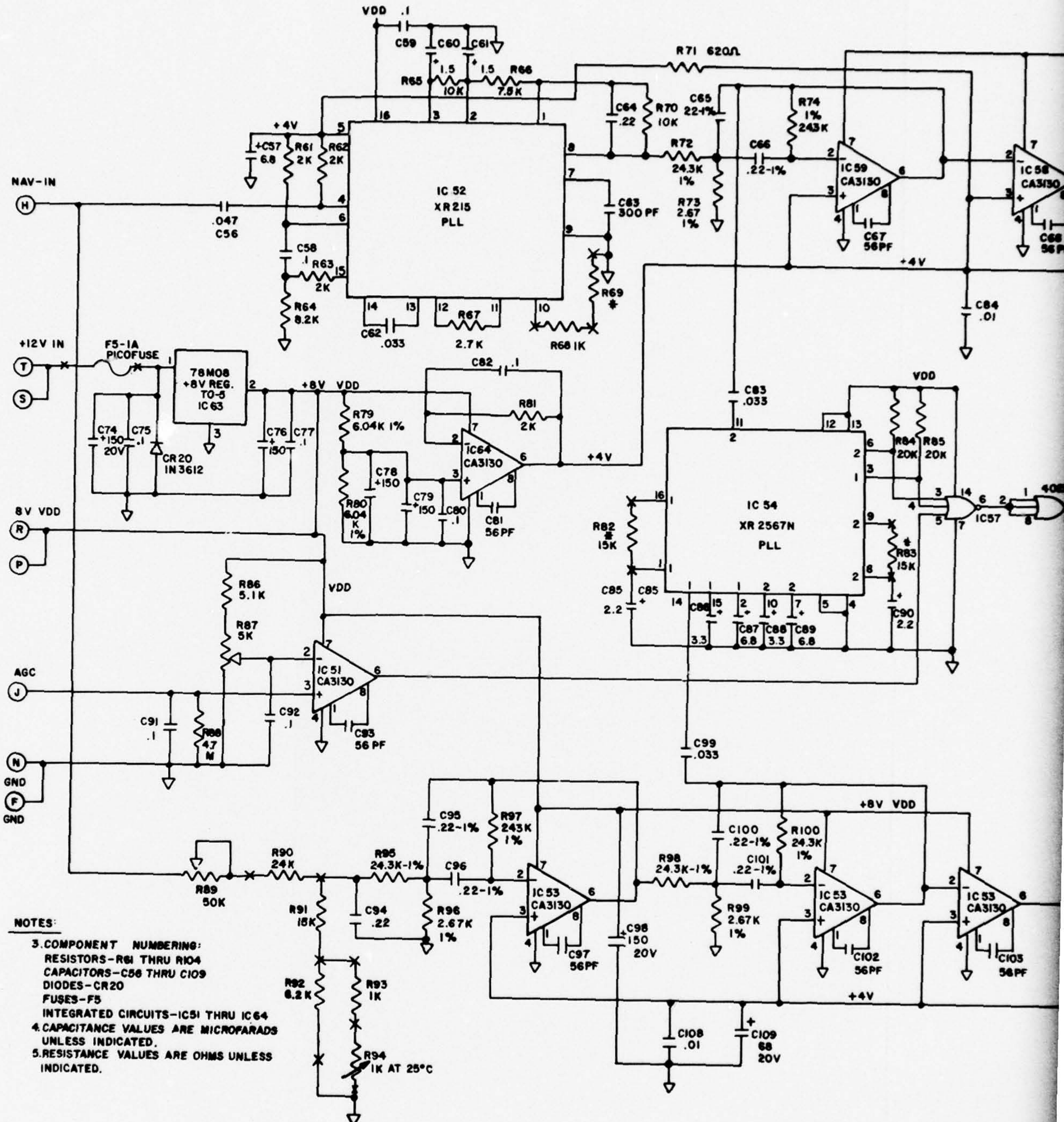

Figure 12. Signal Process

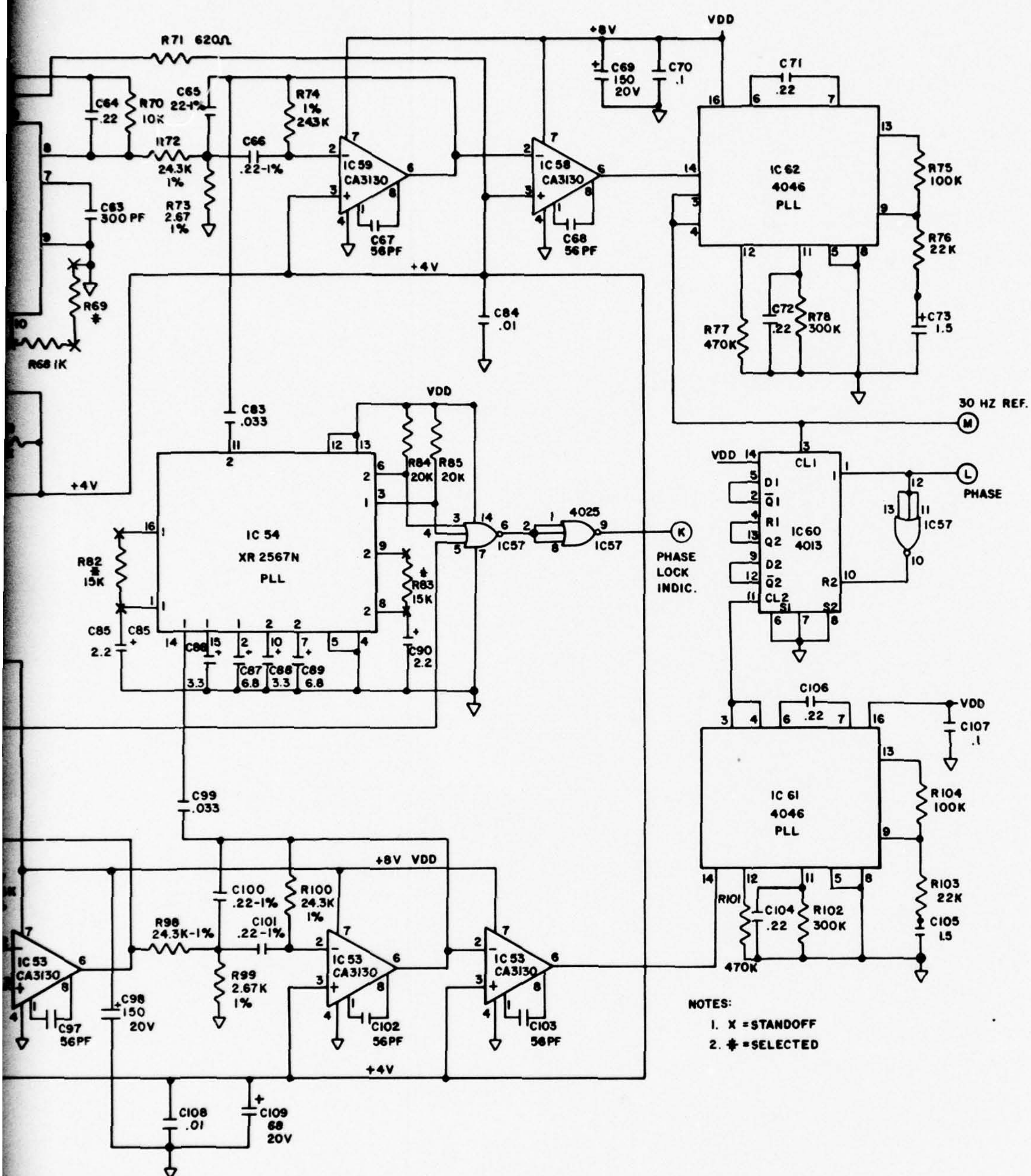

Figure 12. Signal Processor Schematic Diagram

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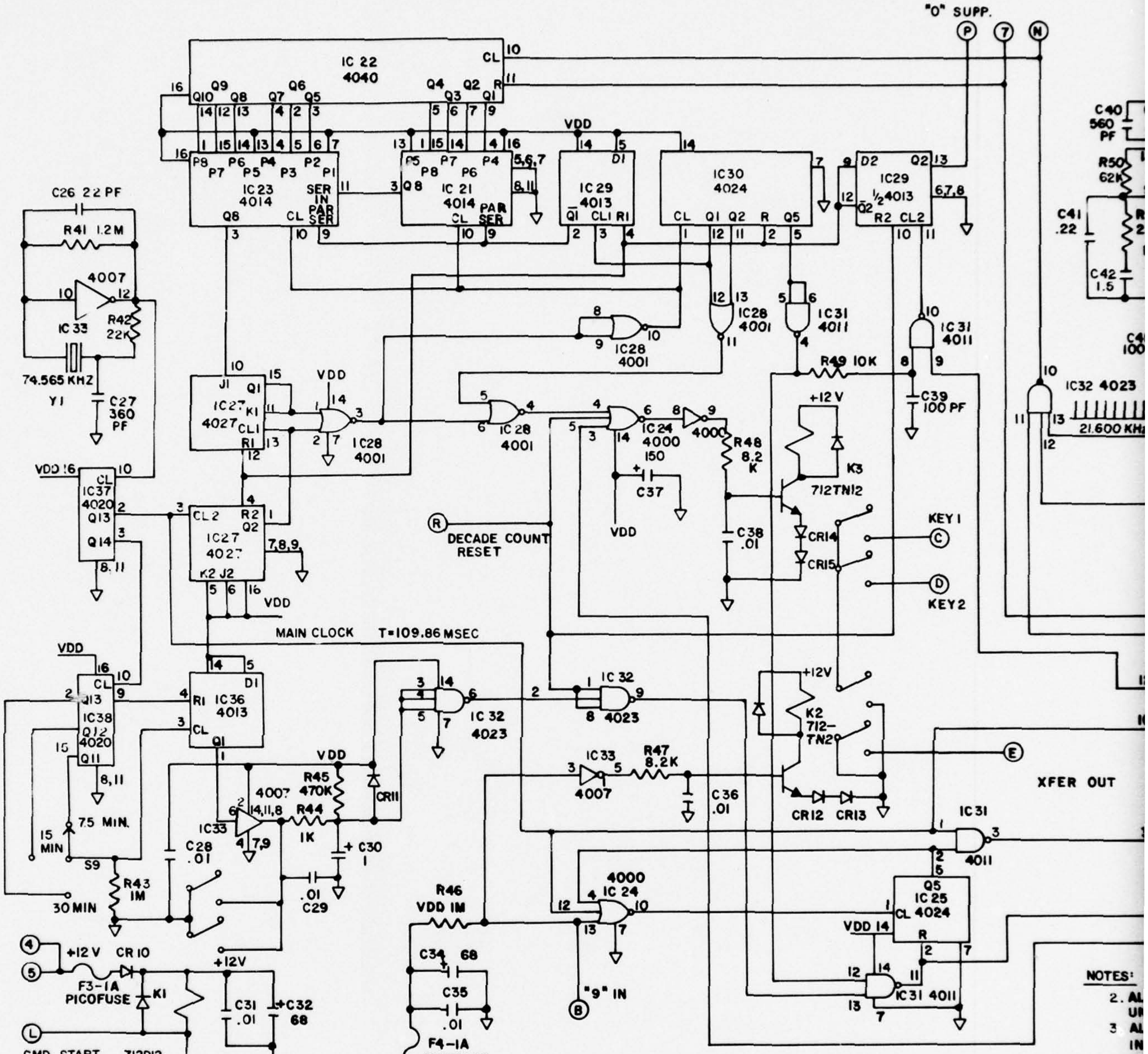
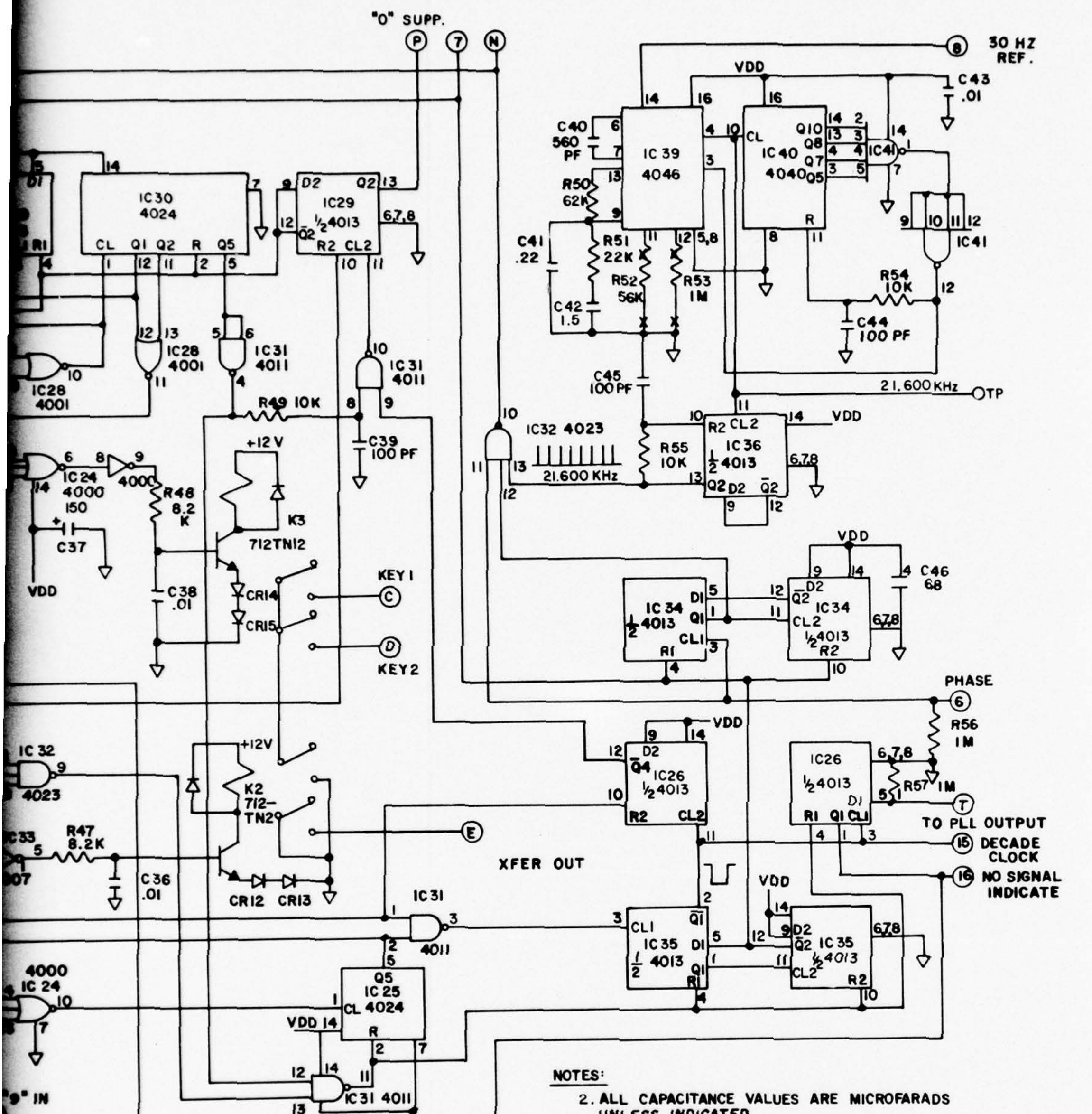


NOTES:

1. COMPONENT NUMBERING
   RESISTORS - R41 THRU R57
   CAPACITORS - C26 THRU C46
   DIODES - CR10 THRU CR15
   INTEGRATED CIRCUITS - IC21 THRU IC41
   FUSES - F3 AND F4
   RELAYS - K1 THRU K3
   SWITCHES - S9

Figure 13. Phase Encod

2



NOTES:

2. ALL CAPACITANCE VALUES ARE MICROFARADS UNLESS INDICATED.
3. ALL RESISTANCE VALUES ARE OHMS UNLESS INDICATED.
4. ALL DIODES ARE IN483B

NOTES:

1. COMPONENT NUMBERING
   RESISTORS - R41 THRU R57
   CAPACITORS - C26 THRU C46
   DIODES - CR10 THRU CR15
   INTEGRATED CIRCUITS - IC21 THRU IC41
   FUSES - F3 AND F4
   RELAYS - K1 THRU K3
   SWITCHES - S9

Figure 13. Phase Encoder Schematic Diagram

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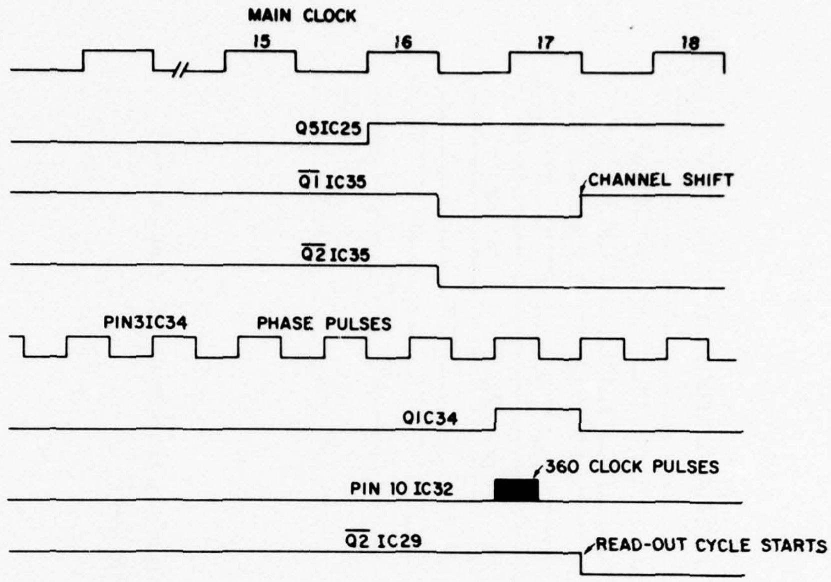
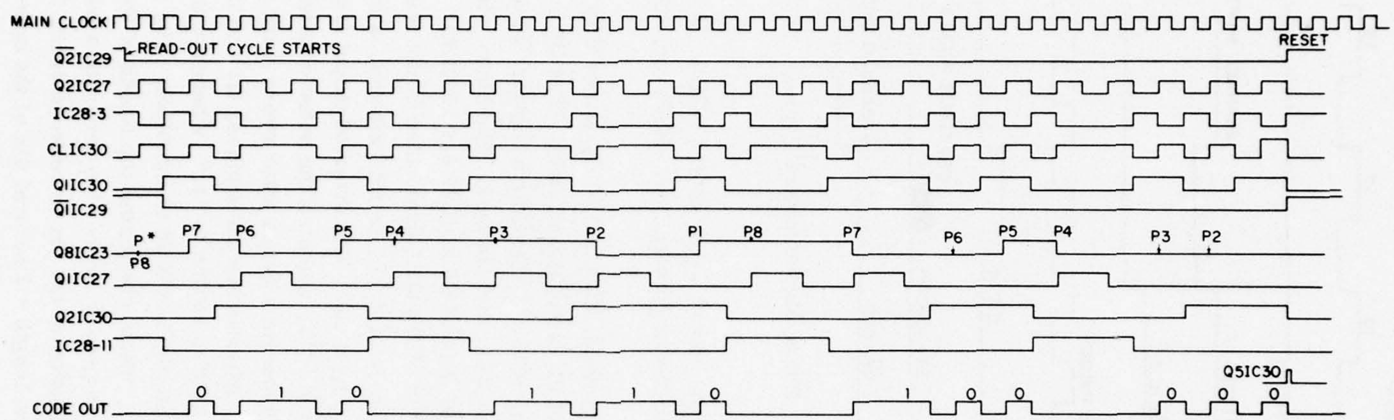


Figure 14. Phase Measurement Cycle

2640 octal which translates into the Morse Code letters RGDS. In order to keep a uniform code, 2 bits are added to the last character. However, bits 11 and 12 are always 0.

The content of both shift-registers, IC21 and IC23, is serially shifted out on Q8 of IC23. The most significant bit is generated first. The Q8 output of IC23 feeds the J1 input of the flip-flop, IC27. Everytime a logical "1" appears on J1-IC27 the frequency into CL1-IC27 is divided by 2. However, when J1 is 0 the division is inhibited. The outputs Q1 and Q2 of IC27 are "NORED" together such that a pulse of 3 times the duration of the Q2 output pulse (a dot length) is generated whenever a logical "1" appears on J1 of IC27. In this manner, a binary 1 is represented by a dash and a binary 0 by a dot. The inverted output from pin 3 of IC28 clocks the shift-registers, IC21 and IC23, and also the pulse counter, IC30. This pulse counter, IC30, is used to generate a pause after every third bit and also to sense the end of message pulse. After every third pulse, Q1 and Q2 of IC30 are both "0" which causes pin 11 to IC28 to switch to "1." Whenever the output on Pin 11 of IC28 is a "1" the code on pin 6 of IC28 is inhibited. The preset inputs P5 and P1 of IC23 and P5 of IC21, which determine the length of the pause, are connected to "1," therefore, these preset inputs also generate a pulse which is 3 times a dot length. The total duration of the pause between every 3 bits or character is 5 times a dot length (a dash length + 2 natural 0's of the code wave form).



*CONTENTS OF PHASE COUNTER !C22 JAMMED INTO IC2I &IC23 SHIFT REGISTER (IC23:P8 = 0, P7 = 1, P6 = 0, P5 = 1, P4 = 1, P3 = 1 P2 = 0, P1 = 1, IC2I: P8 = 1, P7 = 0, P6 = 0, P5 = 1, P4= 0, P3, P2, P1 = 0 FOR 180° PHASE DIFF.)

Figure 15. BLS-3 Readout Cycle

The code output on pin 4 of IC28 is inverted twice by IC24. The output of IC24 (pin 9) activates the keying relay, K3. The keying outputs of K3 are only activated when K2 is energized. Relay K2 is energized as long as the "9" output of IC13, the channel counter, on the programming board is 0. The "9" output of IC13 stays low until 8 channel messages, a pause, and the phase measurement of an apparent extra channel are completed. However, the receiver is not tuned to any frequency on channel 9, therefore, the BLS-3 test box will indicate an unusable signal for channel 9 (all 8's). After the phase measurement of the apparent extra channel the "9" output of IC13 switches to "1" which de-energizes relay K2 and, therefore, inhibits the code output of the channel. The transfer signal output (pin E) of K2 is used when the BLS-3 code output is commutated with code outputs of other devices.

The counter, IC30, counts the number of pulses contained in a code message. Then Q5 of IC30 switches to "1." After a small time delay, determined by R49 and C39, the CL2 input of IC29 causes $\overline{Q2}$ of IC29 to switch to a "1." This disables the reset lines R1 of IC27, R of IC30, and R1 of IC29. The Q5 pulse output of IC30 causes a momentary reset of IC25. This will generate the next pause if the "9" output of IC13, the channel counter, is still 0.

A code output is only generated if Q1 of IC26, which feeds pin 3 of IC24, is low at the end of a phase measurement cycle. After every measurement the state of D1-IC26 is transferred to Q1-IC26. The state of D1-IC26 is controlled by the signal processor. If a usable signal is received by the signal processor, D1-IC26 is low after the phase measurement. However, if an unusable signal is received D1-IC26 is high, which causes Q1-IC26 to switch to a "1." Therefore, a continuous dash is generated indicating an unusable signal. This long dash stops after 16 meaningless pulses are counted by IC30. The Q1-IC26 output also feeds the lamp test lines of the 7-segment display counters in the BLS-3 test box, therefore, an unusable signal is indicated by a display of three 8's.

After eight read-out cycles, the "9" output of IC13 of the programming board switches to a logical "1," which disables pin 10 of IC24. This action stops the read-out cycle. The system is started again by its timer or by an external command.

5. PRE-FLIGHT TEST AND CALIBRATION

The following equipment is needed to calibrate and test the BLS-3 instrument:

(a) Power supply (12 Vdc at 0.5 A).

(b) Tel-Instrument Electronics Corp., T-12A NavCom signal generator or equivalent.

(c) Collins SG-13/ARN NavCom signal generator or equivalent.

(d) BLS-3 test box.

5.1 Phase Calibration

(a) Adjust and calibrate the TIC-T12A signal generator as per the instruction manual.

(b) Set the test signal selector on the T-12A to VOR-"TO" Ø ANGLE.

(c) Set the phase angle selector on the T-12A to 90°.

(d) Set the RF attenuator on the T-12A for a 100 μV output signal.

(e) Connect the BLS-3 instrument, the power supply, the TIC-T-12A generator, and the BLS-3 test box as shown in Figure 16.

(f) Program channel 1 of the BLS-3 to the frequency on the T-12A XTAL Selector switch.

(g) Set the BLS-3 Manual/Operate switch, S10, to channel 1.

(h) Turn on the power supply and note the bearing angle displayed on the BLS-3 test box. The bearing display on the test box consists of three, 7-segment read-outs and a single indicator lamp. The three read-outs display whole degrees. When the indicator lamp is on, 0.5 deg is added to the angle.

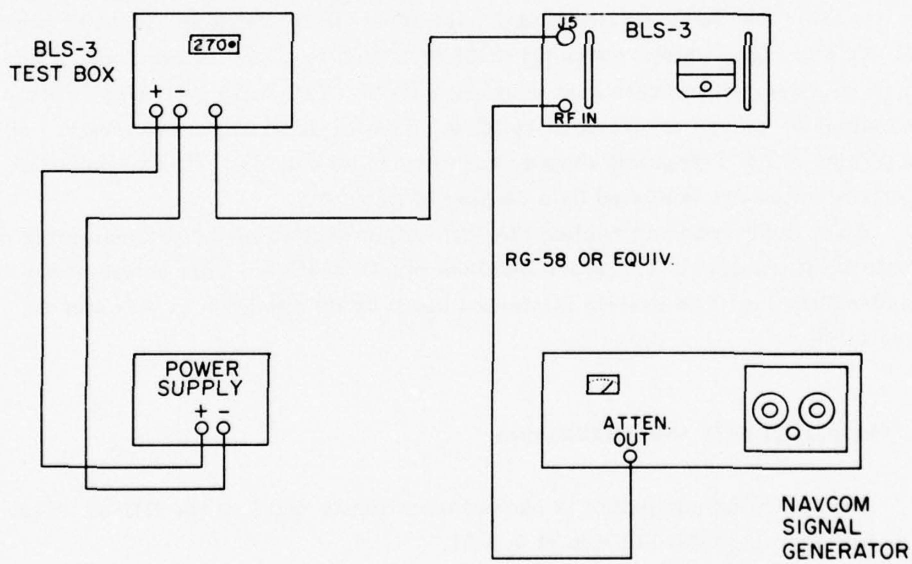


Figure 16. BLS-3 Test Configuration

(i) If necessary, adjust the phase potentiometer, R89, located on the signal processor circuit board (see Figure 9), until the test box displays a bearing angle of exactly 270.0°.

NOTE

The BLS-3 measures bearing angles "FROM" a VOR station, hence, 270° "FROM" is equivalent to 90° "TO."

(j) Set the KEY ENABLE switch on the test box to either KEY 1 or KEY 2 and copy the Morse code.

(k) Using the BLS-3 code dictionary, convert the Morse code to the corresponding bearing angle and compare it with the display on the test box.

5.2 Threshold Sensitivity Test

(a) Adjust and recalibrate the T-12A signal generator.

(b) Set the RF attenuator for a 1-μV output signal.

(c) Slowly increase the RF output signal until a bearing angle is obtained on the test box display. This signal level is the threshold sensitivity of the VOR receiver.

(d) If necessary, turn the threshold adjust potentiometer, R87, located on the signal processor circuit board (see Figure 9), until a threshold sensitivity of 10 μV is obtained.

5.3 Frequency Program Verification

(a) Program the BLS-3 for the eight VOR frequencies selected for flight.

(b) Substitute the Collins SG-13/ARN signal generator for the T-12A generator in the test configuration of Figure 16. Refer to the SG-13/ARN manual for calibration procedures. The SG-13 generator is used because it can be quickly set to operate on any frequency in the VOR band.

(c) Set the BLS-3 MANUAL/OPERATE switch, S10, to channel 1 and the SG-13 frequency selector to the corresponding VOR frequency.

(d) Set the RF attenuator on the SG-13 generator for a 100-μV output signal.

(e) Set the SG-13 phase angle selector to 90 deg.

(f) Turn on the power supply, copy the Morse code bearing angle, and compare it with the angle displayed on the test box.

NOTE

> Due to differences in tolerances between the SG-13 and T-12A generators, this angle may not be 270.0 deg as previously calibrated. However, it should be within $\pm 3^{\circ}$ of this angle. The accuracy of the bearing angle is not the important factor in this test. The presence of a bearing angle is sufficient to verify correct programming.

(g) Verify the frequencies programmed on channels 2 through 8 in the same manner.

5.4 Readout Interval Test

(a) Locate the timer switch, S9, on the phase encoder circuit board (see Figure 17).

(b) Set this switch to the time interval desired between BLS-3 readouts (7.5, 15, or 30 min).

(c) Apply power and time this interval.

NOTE

> Due to timer circuit operation, the interval between the 1st and 2nd read-out cycles after power turn-on is always one-half of the selected timer setting. Therefore, the time interval between the start of the 2nd and the start of the 3rd read-out cycles should be used for this test.

6. PARTS LIST

The following qualification exists for the parts listed:

(a) All resistors are fixed, carbon composition type, 1/4-watt, 5 percent tolerance unless otherwise specified.

(b) All capacitors have a 10 percent tolerance unless otherwise specified.

Refer to Figures 17, 18 and 19 for location of components listed.

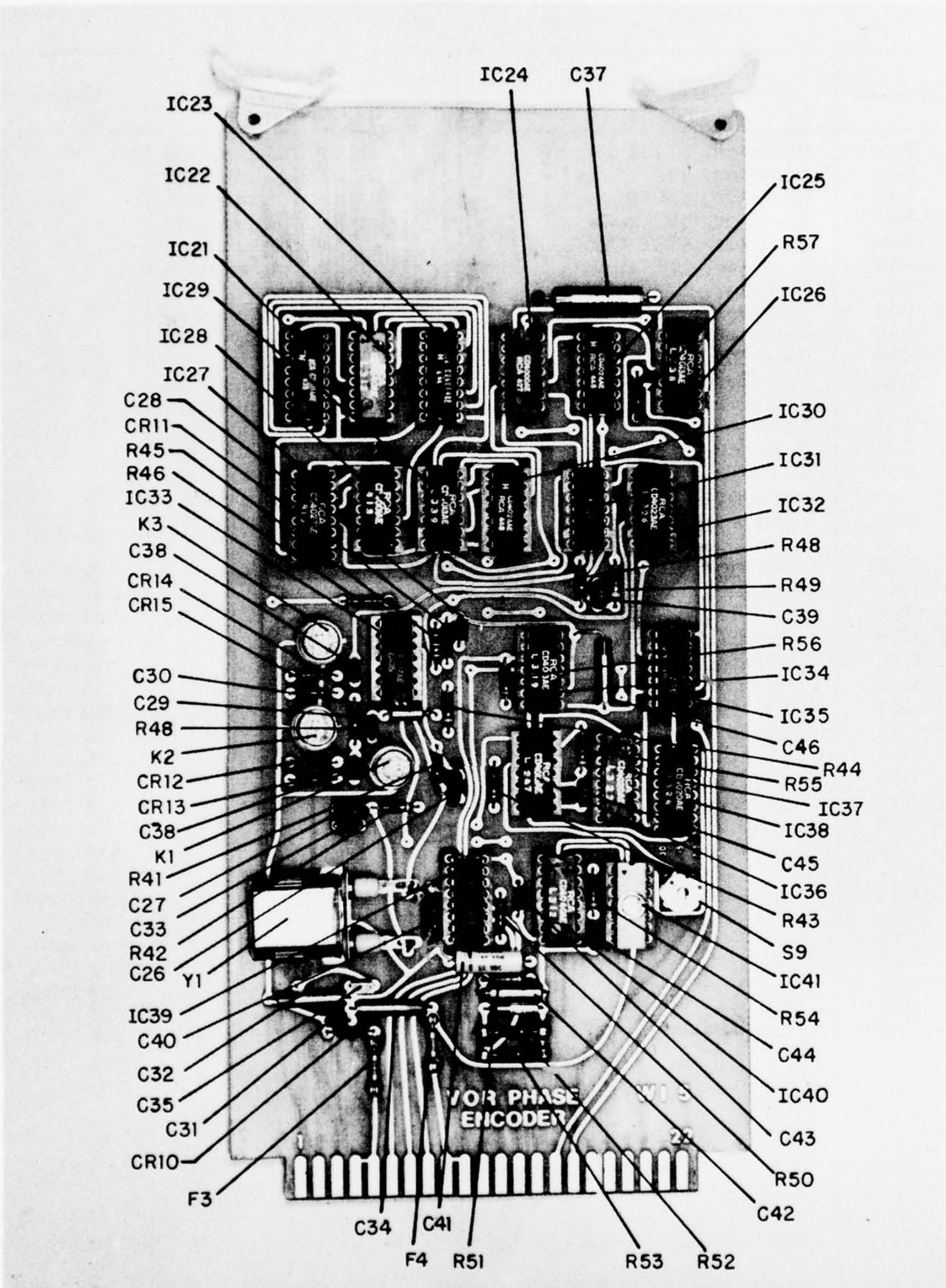


Figure 17. Phase Encoder Component Layout

Parts List
Phase Encoder

Symbol	Description	Part No. or Type	Vendor
R41	Resistor, 5.1M Ohms	Carbon Composition	
R42	Resistor, 22K Ohms	Carbon Composition	
R43	Resistor, 1M Ohms	Carbon Composition	
R44	Resistor, 1K Ohms	Carbon Composition	
R45	Resistor, 470K Ohms	Carbon Composition	
R46	Resistor, 1M Ohms	Carbon Composition	
R47	Resistor, 8.2K Ohms	Carbon Composition	
R48	Resistor, 8.2K Ohms	Carbon Composition	
R49	Resistor, 10K Ohms	Carbon Composition	
R50	Resistor, 62K Ohms	Carbon Composition	
R51	Resistor, 22K Ohms	Carbon Composition	
R52	Resistor, 56K Ohms	Carbon Composition	
R53	Resistor, 1M Ohms	Carbon Composition	
R54	Resistor, 10K Ohms	Carbon Composition	
R55	Resistor, 10K Ohms	Carbon Composition	
R56	Resistor, 1M Ohms	Carbon Composition	
R57	Resistor, 1M Ohms	Carbon Composition	
C26	Capacitor, 10pf, 100V	CM4	Sangamo
C27	Capacitor, 470pf, 100V	CM4	Sangamo
C28	Capacitor, .01 μf, 100V	CK05BX103K	Aerovox
C29	Capacitor, .01 μf, 100V	CK05BX103K	Aerovox
C30	Capacitor, 1 μf, 35V	150D105X9035B	Sprague
C31	Capacitor, .01 μf, 100V	CK05BX103K	Aerovox
C32	Capacitor, 68 μf, 15V	MMTP686M015P1B	Mallory
C33	Capacitor, .01 μf, 100V	CK05BX103K	Aerovox
C34	Capacitor, 68 μf, 15V	MMTP686M015P1B	Mallory
C35	Capacitor, .01 μf, 100V	CK05BX103K	Aerovox
C36	Capacitor, .01 μf, 100V	CK05BX103K	Aerovox
C37	Capacitor, 150 μf, 20V	MMTP157M020P1C	Mallory
C38	Capacitor, .01 μf, 100V	CK05BX103K	Aerovox
C39	Capacitor, 100pf, 100V	CM4	Sangamo
C40	Capacitor, 560pf, 100V	CM4	Sangamo
C41	Capacitor, .22 μf, 50V, 10%	X463UW	TRW
C42	Capacitor, 1.5 μf, 35V	150D155X9035B	Sprague
C43	Capacitor, .01 μf, 100V	CK05BX103K	Aerovox
C44	Capacitor, 100pf, 100V	CM4	Sangamo
C45	Capacitor, 100pf, 100V	CM4	Sangamo
C46	Capacitor, 68 μf, 15V	MMTP686M015P1B	Mallory
CR10	Diode	1N483B	
CR11	Diode	1N483B	
CR12	Diode	1N483B	
CR13	Diode	1N483B	
CR14	Diode	1N483B	
CR15	Diode	1N483B	
Y1	Crystal, 74.565 kHz	M-1	McCoy
K1	Relay, Hybrid, TO-5	712D-12	Teledyne
K2	Relay, Hybrid, TO-5	712TN-12	Teledyne
K3	Relay, Hybrid, TO-5	712TN-12	Teledyne

Parts List
Phase Encoder (Cont.)

Symbol	Description	Part No. or Type	Vendor
F3	Fuse, 1 Amp	Picofuse	Littlefuse
F4	Fuse, 1 Amp	Picofuse	Littlefuse
IC21	Integrated Circuit, 8-Stage Static Shift Register	CD4014AE	RCA
IC22	Integrated Circuit, 12-Stage Binary Ripple Counter	CD4040AE	RCA
IC23	Integrated Circuit, 8-Stage Static Shift Register	CD4014AE	RCA
IC24	Integrated Circuit, Dual 3-Input NOR Gate Plus Inverter	CD4000AE	RCA
IC25	Integrated Circuit, 7-Stage Binary Counter	CD4024AE	RCA
IC26	Integrated Circuit, Dual "D" Flip-Flop With Set/Reset	CD4013AE	RCA
IC27	Integrated Circuit, Dual J-K Master-Slave Flip-Flop	CD4027AE	RCA
IC28	Integrated Circuit, Quad 2-Input NOR Gate	CD4001AE	RCA
IC29	Integrated Circuit, Dual "D" Flip-Flop with Set/Reset	CD4013AE	RCA
IC30	Integrated Circuit, 7-Stage Binary Counter	CD4024AE	RCA
IC31	Integrated Circuit, Quad 2-Input NAND Gate	CD4011AE	RCA
IC32	Integrated Circuit, Triple 3-Input NAND Gate	CD4023AE	RCA
IC33	Integrated Circuit, Dual Complementary Pair Plus Inverter	CD4007AE	RCA
IC34	Integrated Circuit, Dual "D" Flip-Flop with Set/Reset	CD4013AE	RCA
IC35	Integrated Circuit, Dual "D" Flip-Flop with Set/Reset	CD4013AE	RCA
IC36	Integrated Circuit, Dual "D" Flip-Flop with Set/Reset	CD4013AE	RCA
IC37	Integrated Circuit, 14-Stage Binary/Ripple Counter	CD4020AE	RCA
IC38	Integrated Circuit, 14-Stage Binary Ripple Counter	CD4020AE	RCA
IC39	Integrated Circuit, Micropower Phase-Locked Loop	CD4046AE	RCA
IC40	Integrated Circuit, 12-Stage Binary/Ripple Counter	CD4040AE	RCA
IC41	Integrated Circuit, Dual 4-Input NAND Gate	CD4012AE	RCA
S9	Switch, Rotary, 3-Position	MOD SW-32	Minelco

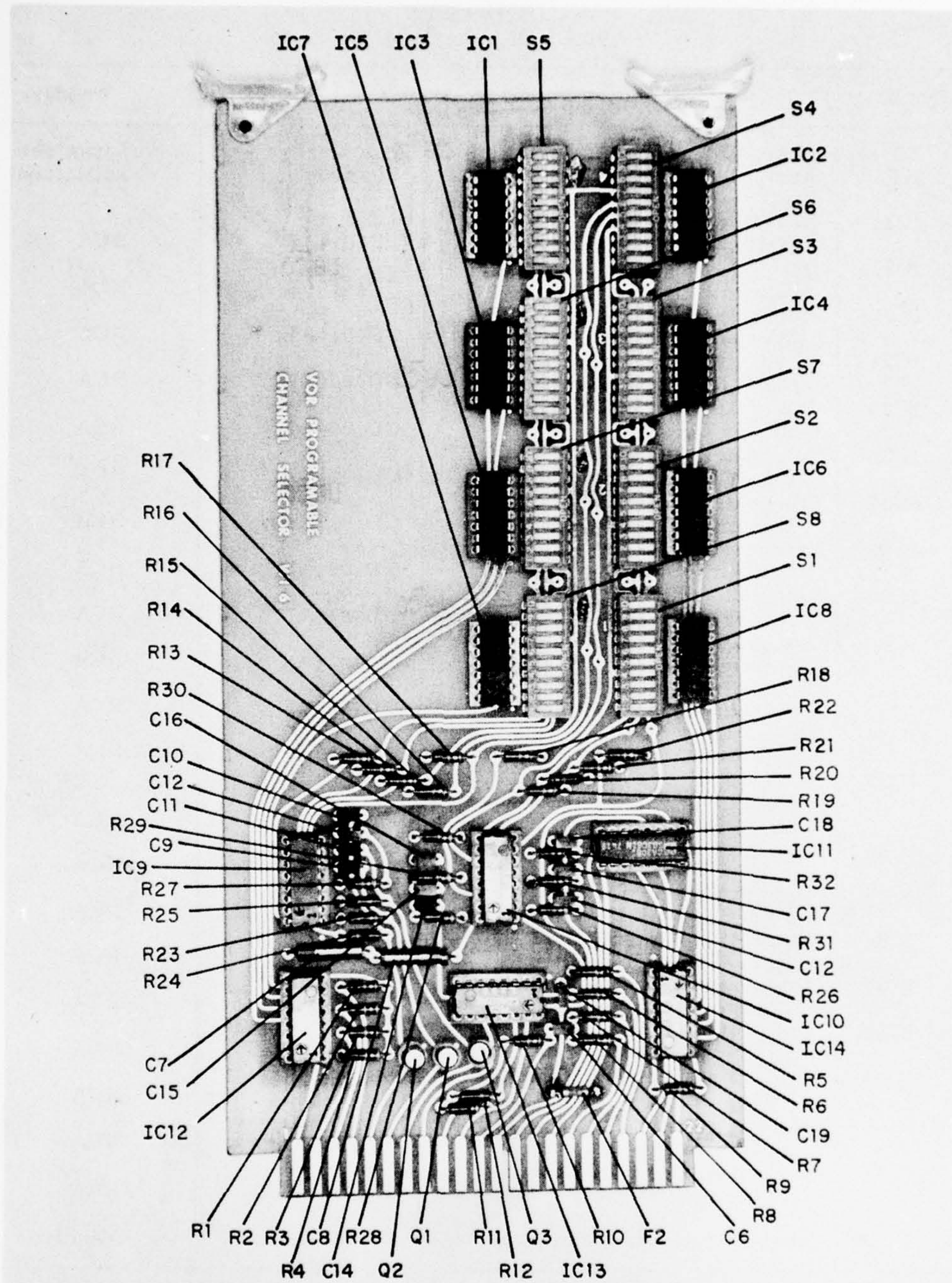


Figure 18. Programmable Channel Selector Component Layout

Parts List
Programmable Channel Selector

Symbol	Description	Part No. or Type	Vendor
R1	Resistor, 100K Ohms	Carbon Composition	
R2	Resistor, 100K Ohms	Carbon Composition	
R3	Resistor, 100K Ohms	Carbon Composition	
R4	Resistor, 100K Ohms	Carbon Composition	
R5	Resistor, 100K Ohms	Carbon Composition	
R6	Resistor, 100K Ohms	Carbon Composition	
R7	Resistor, 100K Ohms	Carbon Composition	
R8	Resistor, 100K Ohms	Carbon Composition	
R9	Resistor, 100K Ohms	Carbon Composition	
R10	Resistor, 1K Ohms	Carbon Composition	
R11	Resistor, 1M Ohms	Carbon Composition	
R12	Resistor, 1M Ohms	Carbon Composition	
R13	Resistor, 100K Ohms	Carbon Composition	
R14	Resistor, 100K Ohms	Carbon Composition	
R15	Resistor, 100K Ohms	Carbon Composition	
R16	Resistor, 100K Ohms	Carbon Composition	
R17	Resistor, 100K Ohms	Carbon Composition	
R18	Resistor, 100K Ohms	Carbon Composition	
R19	Resistor, 100K Ohms	Carbon Composition	
R20	Resistor, 100K Ohms	Carbon Composition	
R21	Resistor, 100K Ohms	Carbon Composition	
R22	Resistor, 100K Ohms	Carbon Composition	
R23	Resistor, 3.3K Ohms	Carbon Composition	
R24	Resistor, 3.3K Ohms	Carbon Composition	
R25	Resistor, 3.3K Ohms	Carbon Composition	
R26	Resistor, 10K Ohms	Carbon Composition	
R27	Resistor, 10K Ohms	Carbon Composition	
R28	Resistor, 10K Ohms	Carbon Composition	
R29	Resistor, 10K Ohms	Carbon Composition	
R30	Resistor, 10K Ohms	Carbon Composition	
R31	Resistor, 10K Ohms	Carbon Composition	
R32	Resistor, 10K Ohms	Carbon Composition	
C6	Capacitor, .01 μf, 100V	CK05BX103K	
C7	Capacitor, 68 μf, 15V	Tantalum MMTP	Mallory
C8	Capacitor, 68 μf, 15V	Tantalum MMTP	Mallory
C9	Capacitor, .01 μf, 100V	CK05BX103K	
C10	Capacitor, .01 μf, 100V	CK05BX103K	
C11	Capacitor, .01 μf, 100V	CK05BX103K	
C12	Capacitor, .01 μf, 100V	CK05BX103K	
C13	Capacitor, .01 μf, 100V	CK05BX103K	
C14	Capacitor, .01 μf, 100V	CK05BX103K	
C15	Capacitor, .01 μf, 100V	CK05BX103K	
C16	Capacitor, .01 μf, 100V	CK05BX103K	
C17	Capacitor, .01 μf, 100V	CK05BX103K	
C18	Capacitor, .01 μf, 100V	CK05BX103K	
C19	Capacitor, .01 μf, 100V	CK05BX103K	
IC1	Integrated Ckt, Diode Matrices	HM1055-2	Harris
IC2	Integrated Ckt, Diode Matrices	HM1055-2	Harris
IC3	Integrated Ckt, Diode Matrices	HM1055-2	Harris
IC4	Integrated Ckt, Diode Matrices	HM1055-2	Harris
IC5	Integrated Ckt, Diode Matrices	HM1055-2	Harris

Parts List
Programmable Channel Selector (Cont.)

Symbol	Description	Part No. or Type	Vendor
IC6	Integrated Ckt, Diode Matrices	HM1055-2	Harris
IC7	Integrated Ckt, Diode Matrices	HM1055-2	Harris
IC8	Integrated Ckt, Diode Matrices	HM1055-2	Harris
IC9	Integrated Ckt, Transistor Array	CA3082	RCA
IC10	Integrated Ckt, Hex Buffer Non-Inverting	CD4010AE	RCA
IC11	Integrated Ckt, Transistor Array	CA3081	RCA
IC12	Integrated Ckt, Quad AND-OR Select Gate	CD4019AE	RCA
IC13	Integrated Ckt, Decade Counter-Divider	CD4017AE	RCA
IC14	Integrated Ckt, Quad AND-OR Select Gate	CD4019AE	RCA
F2	Fuse, 1 amp	FM1041A PICO	Littlefuse
S1	Switch, 10 Position DIP	76B10	Grayhill
S2	Switch, 10 Position DIP	76B10	Grayhill
S3	Switch, 10 Position DIP	76B10	Grayhill
S4	Switch, 10 Position DIP	76B10	Grayhill
S5	Switch, 10 Position DIP	76B10	Grayhill
S6	Switch, 10 Position DIP	76B10	Grayhill
S7	Switch, 10 Position DIP	76B10	Grayhill
S8	Switch, 10 Position DIP	76B10	Grayhill
Q1	Transistor, NPN	2N2222A	
Q2	Transistor, NPN	2N2222A	
Q3	Transistor, NPN	2N2222A	

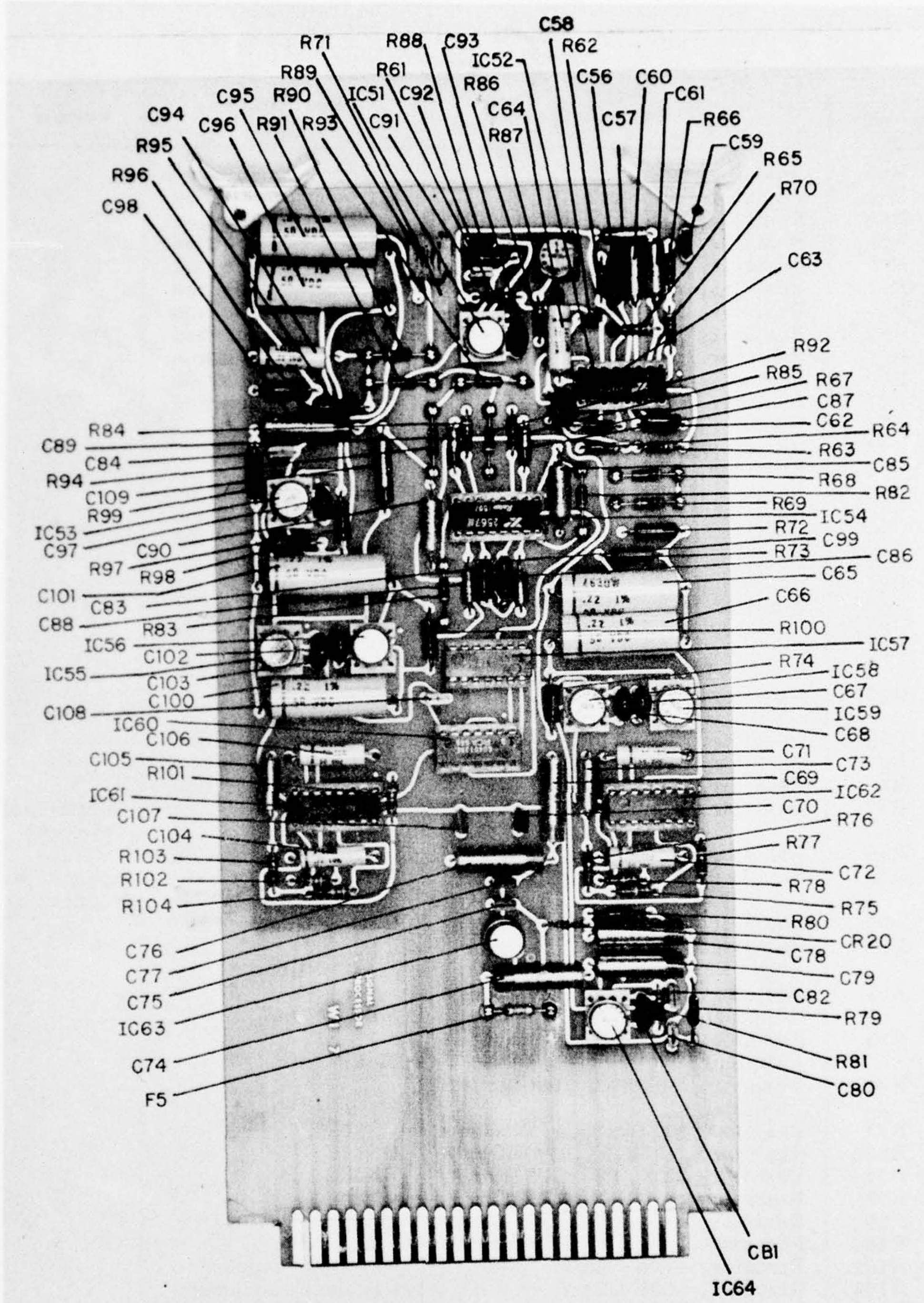


Figure 19. Signal Processor Component Layout

Parts List
Signal Processor

Symbol	Description	Part No. or Type	Vendor
R61	Resistor, 2K Ohms	Carbon Composition	
R62	Resistor, 2K Ohms	Carbon Composition	
R63	Resistor, 2K Ohms	Carbon Composition	
R64	Resistor, 8.2K Ohms	Carbon Composition	
R65	Resistor, 10K Ohms	Carbon Composition	
R66	Resistor, 7.5K Ohms	Carbon Composition	
R67	Resistor, 2.7K Ohms	Carbon Composition	
R68	Resistor, 1K Ohms	Carbon Composition	
R69	Resistor, Selected	Carbon Composition	
R70	Resistor, 10K Ohms	Carbon Composition	
R71	Resistor, 620 Ohms	Carbon Composition	
R72	Resistor, 24.3K,1%, 1/4W Ohms	RN60C	
R73	Resistor, 2.67K,1%, 1/4W Ohms	RN60C	
R74	Resistor, 243K,1%, 1/4 W Ohms	RN60C	
R75	Resistor, 100K Ohms	Carbon Composition	
R76	Resistor, 22K Ohms	Carbon Composition	
R77	Resistor, 470K Ohms	Carbon Composition	
R78	Resistor, 300K Ohms	Carbon Composition	
R79	Resistor, 6.04K,1%, 1/4 W Ohms	RN60C	
R80	Resistor, 6.04K, 1%, 1/4 W Ohms	RN60C	
R81	Resistor, 2K Ohms	Carbon Composition	
R82	Resistor, Selected, 15K Ohms Typical	Metal-Film	
R83	Resistor, Selected, 15K Ohms Typical	Metal-Film	
R84	Resistor, 20K Ohms	Carbon Composition	
R85	Resistor, 20K Ohms	Carbon Composition	
R86	Resistor, 5.1K Ohms	Carbon Composition	
R87	Resistor, Variable, 5K Ohms	7404M	Bourns Inc. Trimpot
R88	Resistor, 4.7M Ohms	Carbon Composition	
R89	Resistor, Variable, 50K Ohms	7444A	Bourns Inc. Trimpot
R90	Resistor, 24K Ohms	Carbon Composition	
R91	Resistor, Selected, 15K Ohms Typical	Metal-Film	
R92	Resistor, Selected, 6.2K Ohms Typical	Metal-Film	
R93	Resistor, Selected, 1K Ohms Typical	Metal-Film	
R94	Resistor, Selected, 1K Ohms Typical	Metal-Film	
R95	Resistor, 24.3K, 1%, 1/4W Ohms	RN60C	
R96	Resistor, 2.67K, 1%, 1/4W Ohms	RN60C	
R97	Resistor, 243K, 1%, 1/4W Ohms	RN60C	
R98	Resistor, 24.3K, 1%, 1/4W Ohms	RN60C	
R99	Resistor, 2.67K, 1%, 1/4W Ohms	RN60C	
R100	Resistor, 243K, 1%, 1/4W Ohms	RN60C	
R101	Resistor, 470K Ohms	Carbon Composition	
R102	Resistor, 300K Ohms	Carbon Composition	
R103	Resistor, 22K Ohms	Carbon Composition	
R104	Resistor, 100K Ohms	Carbon Composition	

Parts List
Signal Processor (Cont.)

Symbol	Description	Part No. or Type	Vendor
C56	Capacitor, .047 μf, 35V	601 PE	TRW
C57	Capacitor, 6.8 μf, 20V	Tantalum MMTP	Mallory
C58	Capacitor, .1 μf, 50V	CK05BX	Aerovox
C59	Capacitor, .1 μf, 50V	CK05BX	Aerovox
C60	Capacitor, 1.5 μf, 20V	Tantalum 150D	Sprague
C61	Capacitor, 1.5 μf, 20V	Tantalum 150D	Sprague
C62	Capacitor, .033 μf, 35V	601 PE	TRW
C63	Capacitor, 300pf	DM-15	El-Menco
C64	Capacitor, .22 μf, 50V	X463UW	TRW
C65	Capacitor, .22 μf, 1%, 50V	463UW	TRW
C66	Capacitor, .22 μf, 1%, 50V	463UW	TRW
C67	Capacitor, .56pf	DM-10	El-Menco
C68	Capacitor, 56pf	DM-10	El-Menco
C69	Capacitor, 150 μf, 20V	MMTP	Mallory
C70	Capacitor, .1 μf, 50V	CK05BX	Aerovox
C71	Capacitor, .22 μf, 50V	X463UW	TRW
C72	Capacitor, .22 μf, 50V	X463UW	TRW
C73	Capacitor, 1.5 μf, 20V	150D	Sprague
C74	Capacitor, 150 μf, 20V	MMTP	Mallory
C75	Capacitor, .1 μf, 50V	CK05BX	Aerovox
C76	Capacitor, 150 μf, 20V	MMTP	Mallory
C77	Capacitor, .1 μf, 50V	CK05BX	Aerovox
C78	Capacitor, 150 μf, 20V	MMTP	Mallory
C79	Capacitor, 150 μf, 20V	MMTP	Mallory
C80	Capacitor, .1 μf, 50V	CK05BX	Aerovox
C81	Capacitor, 56pf	DM-10	El-Menco
C82	Capacitor, .1 μf, 50V	CK05BX	Aerovox
C83	Capacitor, .033 μf, 35V	601 PE	TRW
C84	Capacitor, .01 μf, 50V	CK05BX	Aerovox
C85	Capacitor, 2.2 μf, 35V	150D	Sprague
C86	Capacitor, 3.3 μf, 20V	MMTP	Mallory
C87	Capacitor, 6.8 μf, 20V	MMTP	Mallory
C88	Capacitor, 3.3 μf, 20V	MMTP	Mallory
C89	Capacitor, 6.8 μf, 20V	MMTP	Mallory
C90	Capacitor, 2.2 μf, 35V	150D	Sprague
C91	Capacitor, .1 μf, 50V	CK05BX	Aerovox
C92	Capacitor, .1 μf, 50V	CK05BX	Aerovox
C93	Capacitor, 56pf, 100V	DM-10	El-Menco
C94	Capacitor, .22 μf, 50V	X463UW	TRW
C95	Capacitor, .22 μf, 1%, 50V	463UW	TRW
C96	Capacitor, .22 μf, 1%, 50V	463UW	TRW
C97	Capacitor, 56pf, 100V	DM-10	El-Menco
C98	Capacitor, 150 μf, 20V	MMTP	Mallory
C99	Capacitor, .033 μf, 35V	601 PE	TRW
C100	Capacitor, .22 μf, 1%, 50V	463UW	TRW
C101	Capacitor, .22 μf, 1%, 50V	463UW	TRW
C102	Capacitor, 56pf, 100V	DM-10	El-Menco
C103	Capacitor, 56pf, 100V	DM-10	El-Menco
C104	Capacitor, .22 μf, 50V	X463UW	TRW
C105	Capacitor, 1.5 μf, 20V	150D	Sprague
C106	Capacitor, .22 μf, 50V	X463UW	TRW
C107	Capacitor, .1 μf, 50V	CK05BX	Aerovox

Parts List
Signal Processor (Cont.)

Symbol	Description	Part No. or Type	Vendor
C108	Capacitor, .01 μf, 50V	CK05BX	Aerovox
C109	Capacitor, 68 μf, 20V	MMTP	Mallory
CR1	Diode, Silicon	1N3612	
F1	Fuse, 1 Amp	Picofuse	Littlefuse
IC51	Operational Amplifier, Integrated Circuit	CA3130AT	RCA
IC52	Integrated Circuit, Phase Locked Loop, FM Detector	XR215	XAR
IC53	Integrated Circuit, Phase Locked Loop, Dual Tone Decoder	XR2567N	XAR
IC54	Integrated Circuit, Operational Amplifier	CA3130AT	RCA
IC55	Integrated Circuit, Operational Amplifier	CA3130AT	RCA
IC56	Integrated Circuit, Operational Amplifier	CA3130AT	RCA
IC57	Integrated Circuit, Triple 3-Input NOR Gate	CD4025AE	RCA
IC58	Integrated Circuit, Operational Amplifier	CA3130AT	RCA
IC59	Integrated Circuit, Operational Amplifier	CA3130AR	RCA
IC60	Integrated Circuit, Dual "D" Flip-Flop	CD4013AE	RCA
IC61	Integrated Circuit, Phase Locked Loop	CD4046AE	RCA
IC62	Integrated Circuit, Phase Locked Loop	CD4046AE	RCA
IC63	Integrated Circuit, 8V Regulator	78M08	Fairchild
IC64	Integrated Circuit, Operational Amplifier	CA3130AT	RCA

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Appendix A

Internal Wiring Diagram

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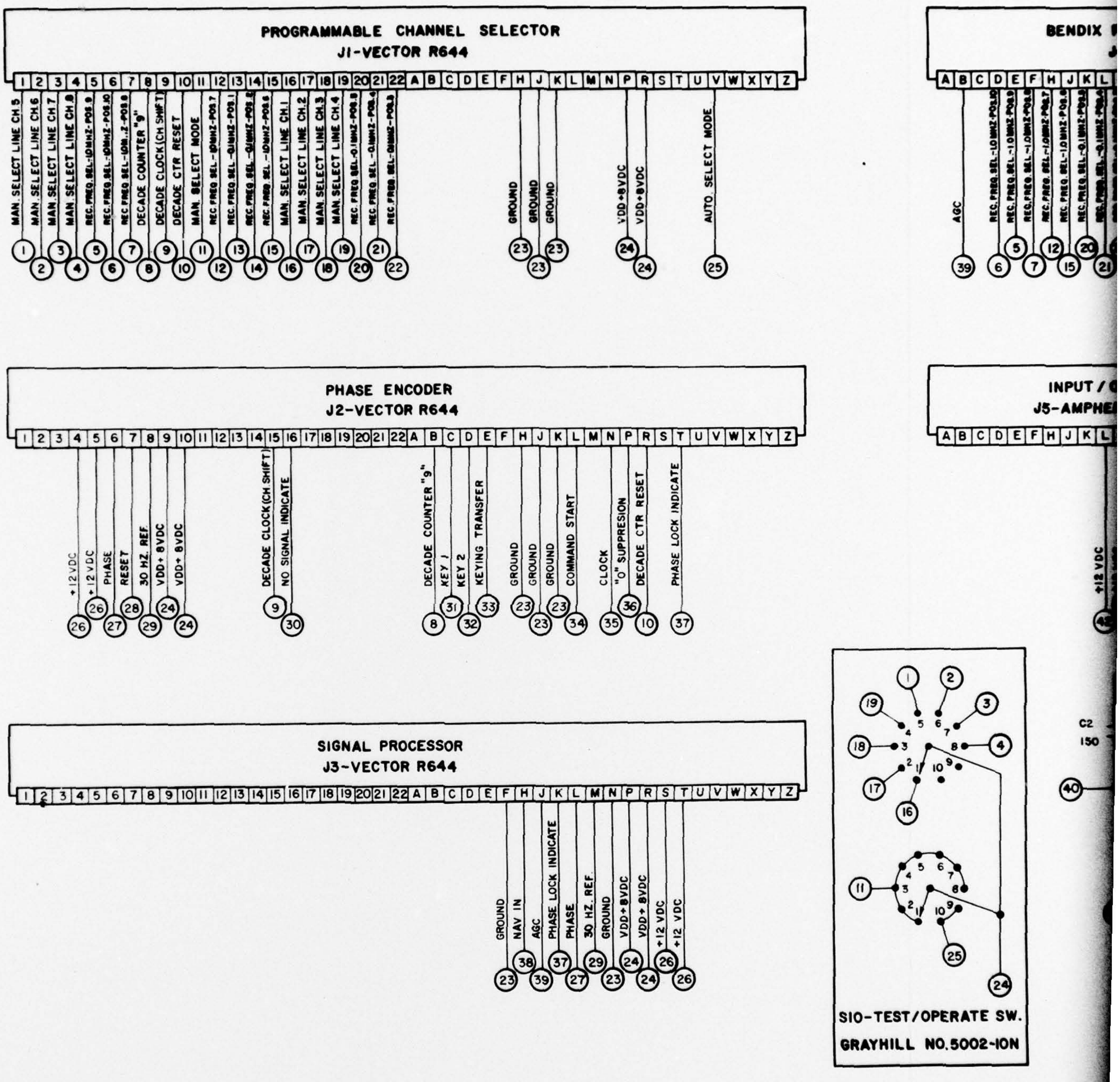

Figure A1. BLS-3 Intern

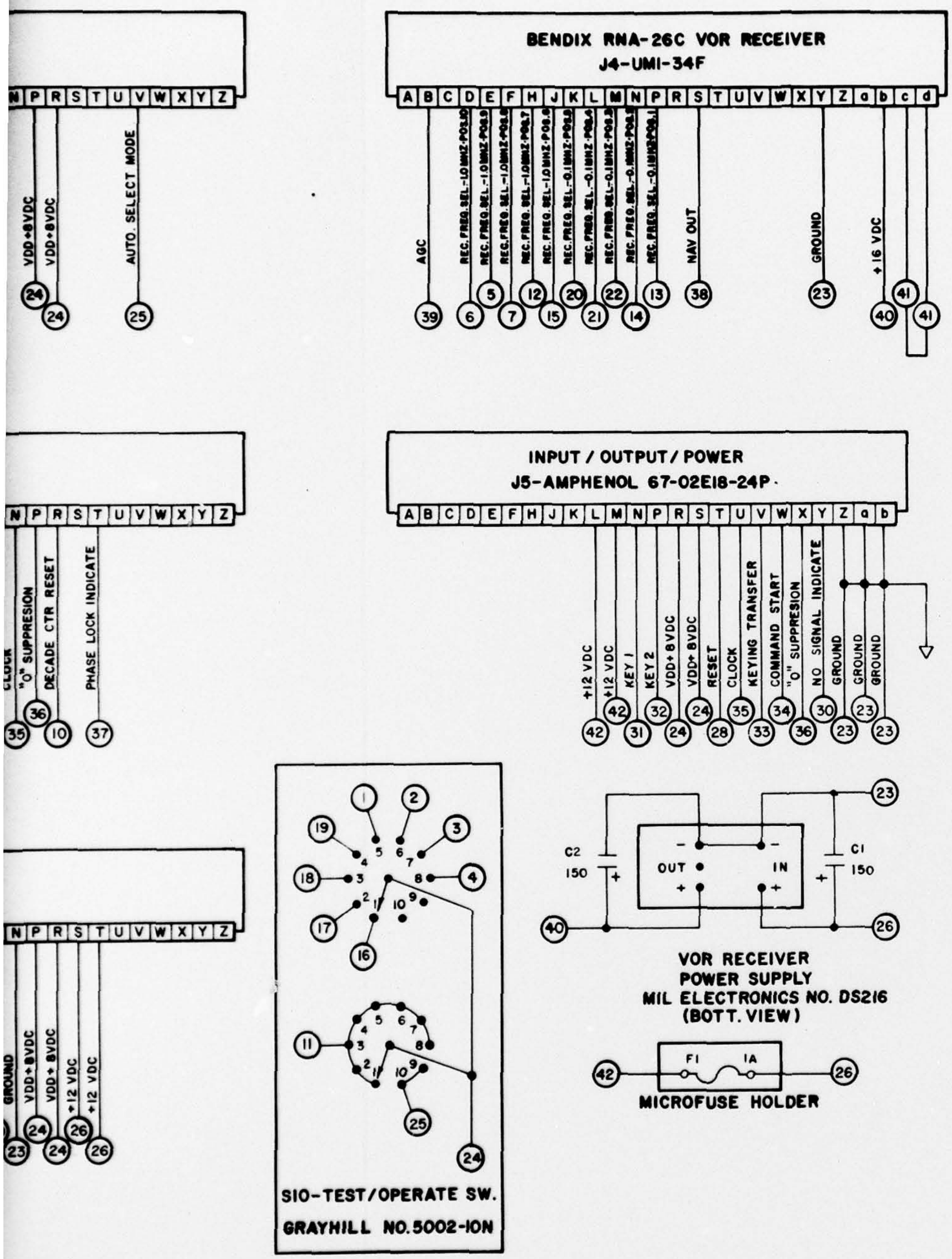

Figure A1. BLS-3 Internal Wiring Diagram